The TREND IN ENGINEERING

at the University of Washington

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OFF-AXIS PERFORMANCE OF MICROWAVE MIRRORS

REFLECTANCE READINGS IN ATMOSPHERIC POLLUTION STUDIES

INVESTIGATION OF POLLUTION IN THE YAKIMA RIVER BASIN

USE OF BASE-FLOW INCREASE IN FLOOD PREDICTION

A DATA-RECORDING SYSTEM FOR THE UNIVERSITY SEISMOLOGICAL STATION

APPARATUS FOR COUNTERCURRENT DISTRIBUTION FRACTIONATION OF MULTICOMPONENT SYSTEMS

July, 1953

Published quarterly

by

THE ENGINEERING EXPERIMENT STATION

The Dolphin or Intake of the Southwark Water Works

An illustration which accompanied a broadside entitled, "Royal Address of . . . Water King of Southwark," . . . a satire on the pollution of the Thames by the Walbrook sewer and other outlets, 1828.

Give us clean water!
Give us pure water
We shall all have the Cholera
What torrents of filth come from that Walbrook Sewer!!
Sewer! why there are 130 Sluices!
Oh never mind any Nastiness goes down here in the Borough
What do they drink that!
Prodigious!
Tell it not in Gath
Devilish thick! yes here I stick. If makes me Sick!
SOURCE OF THE SOUTHWARK WATER WORKS

—From colored print by Cruikshank, reproduced, by permission, from *The Quest for Pure Water* by M. N. Baker, American Water Works Association, Inc., New York, 1948.

In the Quest for Pure Water

India *(c. 2000 B.C.)*

"It is directed to heat foul water by boiling and exposing to sunlight and by dipping seven times into it a piece of hot copper, then to filter and cool in an earthen vessel."

Egypt *(1450 B.C.)*

The siphons probably owed their invention (in Egypt) to the necessity of allowing Nile water to deposit its thick sediment in vases. (See illustration below and note on page 3.)

Greece *(900-400 B.C.)*

A drinking cup which hid badly colored water from the sight of the drinker and caused mud to stick to its sides was invented by Lycurgus. Hippocrates asserted that rain waters should be boiled and strained for otherwise they smell bad and cause hoarseness.

Persia *(600 B.C.)*

Cyrus the Great (according to Herodotus), when going to war took boiled water in silver flagons loaded on four-wheeled carts drawn by mules.

Rome *(77-97 B.C.)*

Pliny wrote the earliest reference to use of lime (chalk) and aluminous earth ("argilla") as precipitants. Frontinus, water commissioner of Rome, was the first engineer to describe a waterworks system. He wrote *Two Books on the Water Supply of Rome.*

China *(?)*

Alum was used to precipitate impurities. "At a very early date" the Chinese began to drink no water except that boiled to infuse their tea.

England *(1675-1683)*

To William Walcott went the first patent for making salt water fresh. Two successful installations of his stills were made on shipboard. Robert Fitzgerald received the second patent. "Mr. Fitz Gerald's method met with such great applause that a Poem was published to celebrate his Praise, and silver Medals were made representing . . . the Art of this New Inventor."

Italy *(1685)*

Porzio, an engineer, wrote the first book on mass sanitation. He recommended "conserving the health of soldiers in camp by multiple filtration (of drinking water) through sand, after straining and sedimentation."

France *(c. 1698)*

The first known case of purification for industrial use was that of a paper mill at Auvergne, consisting of a "flume leading to a water wheel and a branch flume conveying water through grate screens and two small settling basins into the mill."

From *Manners and Customs of the Ancient Egyptians* by J. G. Wilkinson, London, John Murray, 1847.

THE ENGINEERING EXPERIMENT STATION of the University of Washington was established in December, 1917, to coordinate investigations in progress and to facilitate the development of engineering and industrial research in the University. Its purpose is to aid in the industrial development of the state and nation by scientific research and by furnishing information for the solution of engineering problems.

The scope of the work is three-fold:

(1) to investigate and publish information concerning engineering problems of a more or less general nature that would be helpful in municipal, rural, and industrial affairs;

(2) to undertake extended research and to publish reports on engineering and scientific problems;

(3) to provide opportunities for graduate engineers to conduct research under conditions that will most effectively prepare them for professional service.

For administrative purposes the work of the Station is organized into nine divisions:

1. Aeronautical Engineering
2. Chemical Engineering, Industrial Chemistry
3. Civil Engineering
4. Electrical Engineering
5. Forest Products
6. Geology
7. Mechanical Engineering
8. Mining, Metallurgical, Ceramic Engineering
9. Physics Standards and Tests

The control of the Station is vested in a Station Board consisting of the President of the University, the Dean of the College of Engineering as chairman, the Director of the Station, and members of the faculty, representative of the administrative divisions. The Board determines the character of the investigations to be undertaken and supervises the work.

The Station offers a substantial number of research fellowships to highly qualified graduate students who work under the direct supervision of the faculty of the various divisions. Results of major investigations are published in the form of bulletins and reports. Current research findings from the Station's fellowship projects, as well as accounts of its activities, appear in the quarterly journal, *The Trend in Engineering at the University of Washington*. Reprints of articles by members of the engineering faculty and graduate students published in recognized technical journals are also issued by the Station. Requests for copies of the publications and inquiries for information on engineering and industrial problems should be addressed to the Director, Engineering Experiment Station, University of Washington, Seattle 5.

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at the University of Washington

Vol. 5 No. 3

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FRONT PAGE

THE ILLUSTRATION SHOWS "Egyptians siphoning off water or wine clarified by sedimentation, pictured on the wall of the tomb of Amenophis II at Thebes, 1450 B.C." Another mural painting in the tomb of Rameses II (1344-1258 B.C.) portrays assorted sizes of wick siphons in an Egyptian kitchen. Water was stored in vases to provide for periods of unusual turbidity during the inundation of the Nile.

—All text above and on page 1 adapted or quoted from or via *The Quest for Pure Water by* M. N. Baker, American Association of Water Works, Inc., New York. 1948.

MEASURING CERAMIC BEAM DEFLECTION DURING TEST NUMBER 3

Front, l. to r: Professor Clanton, Professor Mueller; *back:* Mr. Powell, Station Director F. B. Farquharson, Civil Engineering Professor A. L. Miller

STRUCTURAL TESTS ON A PRESTRESSED CERAMIC BEAM

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Associate Professor of Mineral Engineering

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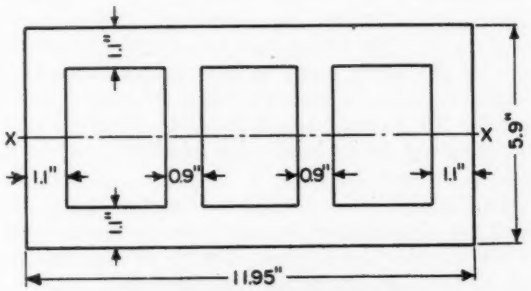
Consulting Engineer, Seattle

IN THE CONSTRUCTION of prestressed structural members, two factors determine to a large extent the cost of the finished product: the formwork and the strength of the material to be stressed. If it is possible to dispense with the construction of forms and, at the same time, to use a high-strength material for prestressing, the utmost economy may be expected.

Under the combined sponsorship of the Builders Brick Company of Seattle and the University of Washington, the writers constructed a prestressed beam of structural clay tile and conducted a series of tests to determine how practical this type of construction might be. Suitable clay products were supplied from the Clay City Plant of the Builders Brick Company.

The first and third tests were made in the Structural Research Laboratory of the Civil Engineering Department, and the second, in the Ceramics Laboratory of the School of Mineral Engineering.

The tile selected for use in the beam had a nominal 12-in. by 12-in. face and 6-in. thickness. The area of the cross section was 41 sq in. for the net section and 70 sq in. for the gross section. The average ultimate compressive strength was approximately 9,000 psi when the load was applied on the net area of the tile end. The modulus of elasticity of the tile when axially loaded was 2,135,000 psi. The tile dimensions and section properties are shown in Fig. 1, and the strength and elastic properties, in Table I. Each tile had its ends ground in order to make pressure on the planes of contact as uniform as possible.



	NET SECT.	GROSS SECT.
A	41.0 SQ. IN.	70.0 SQ. IN.
I_x	171 IN.^{4}	204 IN.^{4}
w	34.5 #/FT.	65 #/FT.

FIG. 1. PROPERTIES OF SECTION

The beam was constructed by using 3/8-in. Roebling 7-wire strand to stress 22 tiles laid end to end. Tensioning of the strands was accomplished by anchoring at one end of the beam and jacking against the other end. The nine strands were loaded to a total of 80,300 lb and were placed to give an eccentricity at the beam ends of 1.24 in. which increased to 1.53 in. at mid-length of the beam because of the upward tensioning camber of 5/8 in. at that point.

TABLE I

PROPERTIES OF TILE STRESSED IN COMPRESSION*

Specimen No.	Ultimate Load (lb)	Ave Unit Load (psi)	Remarks
1	369,000	9,000	Ends of tile ground and capped with plaster of paris
2	362,000	8,830	
3	351,500	8,560	
4	353,000	8,610	
Average		8,750	
5	381,000	9,300	Ends of tile ground but not capped
6	425,500	10,380	
7	425,500	10,380	
8	348,000	8,490	
9	353,000	8,620	
10	381,500	9,290	
Average		9,400	

PROPERTIES OF TILE STRESSED IN TENSION

Ultimate average unit tensile strength = 612 psi
(Average of twelve tests)

AVERAGE PROPERTIES OF BEAM STRESSED IN FLEXURE
(All cells grout-filled)

$EI = 516{,}000{,}000$ lb in.^{2} ($I = 204$ in.^{4})
$E = 2{,}525{,}000$ psi

*Modulus of elasticity when axially loaded in compression = 2,135,000 psi.

FIG. 2. SETUP OF PART 2 OF TEST NUMBER 1 BEFORE LOADING
L. to r: Mr. Gene Salveson of the Seattle Brick Co., Mr. Powell, Professor Clanton

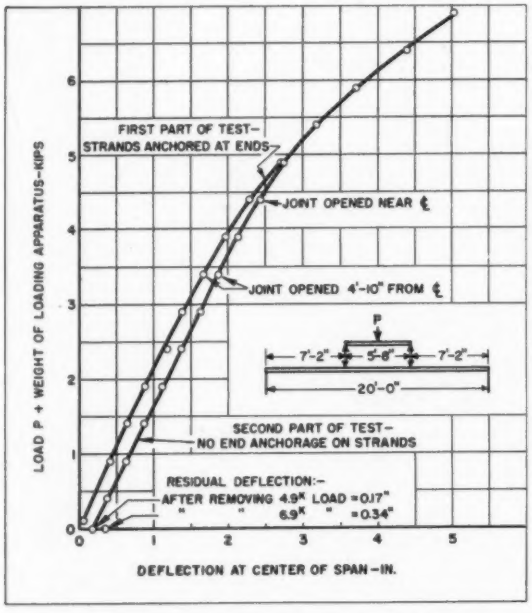


FIG. 3. LOAD VS. DEFLECTION FOR TEST NUMBER 1, PARTS 1 AND 2

Owing to slippage of two of the cable grips, only seven of the nine strands could be stressed, and, because of slip in the grips, an initial tensioning force of 14,000 lb in each strand decreased to about 11,500 lb. The recommended design load for the strand is 12,250 lb. However, inability to have all the strands working at their full allowed value caused no particular concern because the total force developed was as much or more than would ordinarily be required. High local stresses due to the jacking force caused each end tile to crack longitudinally at approximately the center of each face, although later observation indicated no apparent effect on the beam strength. It is believed that solid end blocks should be used when the jacking is done against the beam end; in fact probably the most practical method of tensioning beams of this type is to follow the usual pretensioning method of jacking against isolated anchor blocks.

The final step in constructing the beam was to fill the cells with grout by pouring through a pipe 3 ft long screwed into 1-in. holes drilled through the top flange. The holes were made over each cell at the beam ends and at the third points. In spite of the fact that the grout was applied at all the holes in turn until it was forced out of adjacent holes in the same cell, air pockets were observed at many places when the beam was broken open at the conclusion of the loading tests. The grout was made of high early strength cement and a well-graded builders sand. All proportions, including that for the added aluminum powder, were as recommended in the Handbook of the Bureau of Reclamation. The compressive strength of the grout, as determined by testing 2-in. by 2-in. cubes, was 5,300 psi at an age of eight days.

The first flexure test of the beam, conducted on the day of checking the grout strength, consisted of two parts. The first was with the cable grips in place, and the second, with the grips burned off so that the stress in the strands was retained only by bond with the grout. In the first part of the test the load was increased by 500-lb increments up to a maximum load of 4,900 lb; in the second part the load was applied in the same manner up to a maximum value of 6,900 lb. In each case the beam was on a 20-ft span with the load applied through two points, each 7 ft, 2 in. from the end reaction. The load was applied by a 20-ton hydraulic jack acting against a frame tied into the floor, and the magnitude of load was read on a calibrated pressure gage. At each load increment deflections were measured at the center of the span. The measurements were taken on each side of the beam, and the average was recorded. Figure 2 shows the testing setup at the start of loading for the second part of the test. Figure 3 is a plot showing the load-deflection relationship for each part of the first flexure test.

In Fig. 3 it is interesting to note that the upper limit for elastic action is higher for the second part of the test than for the first. The EI value computed for the straight-line portion of the second curve is 513,000,000, which is nearly the same as might be computed for the first curve. The E value for the gross beam section is computed to be 2,520,000 if the value of I is taken as 204 in.[4] (See Fig. 1.)

Tile joints that opened during the test closed when the load was removed, and there was no apparent cable slip, spalling of tile, or other permanent

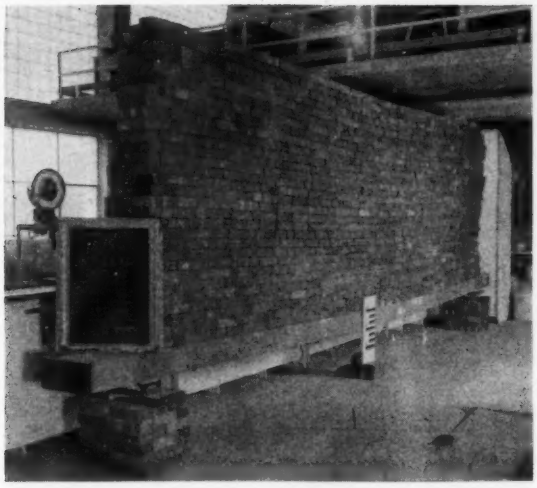


FIG. 4. BEAM LOADED WITH BRICK FOR FLEXURE TEST NUMBER 2

damage. The residual deflection for the first part of the test was 0.17 in., and for the second, 0.34 in., these values being referred to the beam position at the start of the first test. Therefore, in each part of the test, the beam retained a deflection of 0.17 in., as measured from the beam position at the start.

The second flexure test consisted of placing brick on the beam, as shown in Fig. 4, so that the increase in deflection due to a load being continuously applied over an appreciable interval of time might be determined. The maximum brick load applied was 750 lb per foot, which caused a deflection of 2.97 in. at the center of the 18-ft span. Twenty-four hours after the completion of loading, the increase in deflection was 0.03 in., and thereafter, to the end of the loading time of eight days, no additional deflection was observed.

The third flexure test was conducted in the same manner as the first except that the load was applied at the third points of an 18-ft span. The photograph of Fig. 5 was taken when the total load was 10,500 lb and the deflection was almost 6 in.

A plot of the load-deflection relationship (Fig 6) shows that the elastic properties of the beam remained essentially the same as found in the second part of the first test. The upper limit for elastic action at a 4,000-lb load corresponds to a bending moment of 12,000 ft-lb, while in test number one the elastic limit at a 3,400-lb load corresponds to 12,200 ft-lb. The EI product for the beam, as computed for the straight-line portion of the curve, is 519,000,000, and the E value is then 2,530,000 if the moment of inertia for the gross section is used in the computation. The average of the E values for tests numbers one and three is then 2,525,000.

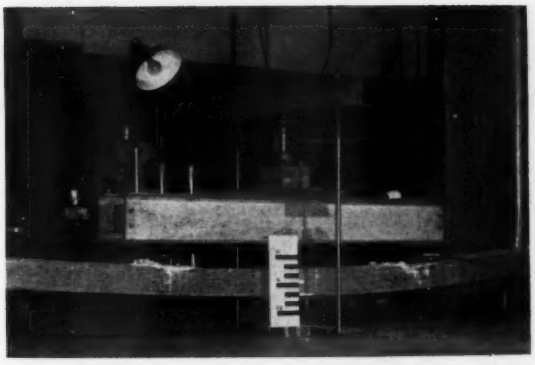


FIG. 5. BEAM DEFLECTION FOR TEST NUMBER 3 (Load: 10,500 lb)

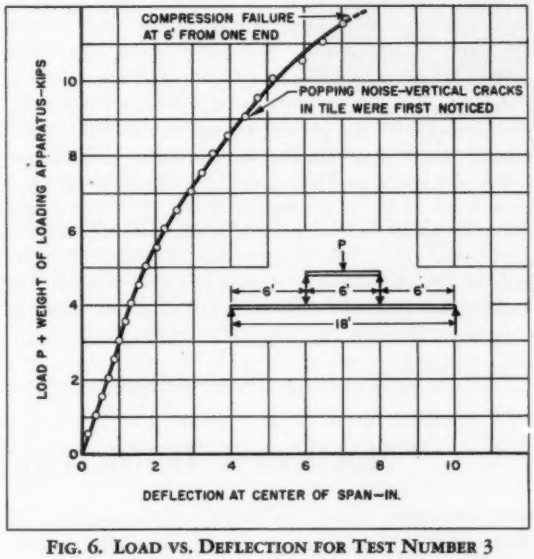


FIG. 6. LOAD VS. DEFLECTION FOR TEST NUMBER 3

At a load of approximately 9,000 lb, popping noises were heard in the beam, and narrow vertical cracks in the tile were noted. These cracks were irregularly spaced between the points of load application and extended from the bottom of the beam to approximately the mid-depth. From this point on, no additional signs of distress were noted before failure at a load of approximately 11,900 lb. The failure was on the compression side of the beam and was due to the sudden and almost complete fragmentation of the tile over a distance of two or three feet on each side of one of the points of load application. (See Fig. 7.) Inspection of the broken beam gave no indication of strand slippage; the imprint of the strand

in the grout was clear, sharp, and unspalled. It was noted that this beam remained intact for a length of about 7 ft from one end and apparently retained its prestress.

The sudden and complete compression failure forcefully points out the desirability of using smaller amounts of steel reinforcement. Beam distress should be indicated by excessive yield in the steel before there is danger of catastrophic compression failure. The test beam would have carried practically the same ultimate load with a much smaller amount of tensioning steel. The load-carrying ability of the beam was found to be very good, and its stiffness is believed to be adequate for most types of service loading; for many combinations of span and load the deflection need not be much greater than the tensioning camber.

An important consideration always is the adequacy of bond between the stressed materials—in this case between the steel and the grout and between the grout and the tile. As stated above, the bond in this beam proved to be adequate, and the evidence indicates the strand used in this test will develop good bond with the grout. However, careful consideration must be given the development of bond between the grout and the tile. The tile when grouted should be moist so as not to draw too much water from the grout, and care must be taken to see that the grout completely fills the tile cell and thereafter has little if any shrinkage. Scoring the inside of the tile would probably aid materially in the development of positive bond.

FIG. 7. FAILURE: TEST NUMBER 3
(Load: 11,900 lb)

The high-strength tile used in this series of tests were supplied by the Builders Brick Company of Seattle, and the writers are indebted to Mr. C. A. Houlahan, president of the company, for his valuable assistance.

Northwest Traffic Engineers Hold Sixth Meeting

THE SIXTH ANNUAL NORTHWEST CONFERENCE on Traffic Engineering was held on the campus May 21, 22, under the joint sponsorship of the Western Section of the Institute of Traffic Engineers, the Civil Engineering Department of the University of Washington, and the State Highway Department, with Civil Engineering Professor R. G. Hennes as general chairman.

The program opened with addresses of welcome by representatives of the sponsoring bodies; Professor R. B. Van Horn, Executive Officer of the Civil Engineering Department; Dean H. E. Wessman, of the College of Engineering; R. A. Moisio of the Washington State Highway Commission, W. A. Bugge, Director of the State Department of Highways, and D. S. Berry, Assistant Director of the Institute of Transportation and Traffic Engineering of the University of California. Papers were read on "Highway Hurdles" by Carl E. Fritts of the Automotive Safety Foundation, Washington, D.C., and "Some Considerations in Toll Road Analysis," by Norman Kennedy, of the Institute of Transportation and Traffic Engineering of the University of California. Three stimulating panel discussions followed on "Limited Access Highways, Design and Control," "The Parking Problem," and "Minor Intersection Traffic Control by Signs or Traffic Beacons."

Field inspection trips were made to the new Alaskan Way viaduct, the Northgate suburban shopping center, government locks, and Lake Washington Floating Bridge. About 150 engineers were registered for the conference, chiefly from Washington, Oregon, California, Utah, and British Columbia, with one representative each from Washington, D.C., Arizona, and Connecticut.

OFF-AXIS PERFORMANCE OF MICROWAVE MIRRORS

JOE E. NANEVICZ
Graduate Student in Electrical Engineering

A. E. HARRISON
Professor of Electrical Engineering

J. E. Nanevicz

Increased interest in the application of plane reflectors for microwave transmission paths has emphasized the need for more information on the transmission characteristics of such systems. Although this information may be known by the commercial organizations engaged in this field, very little of these data have ever been published. Some theoretical studies have appeared,[1,2,3] but there has been very little experimental verification of analytical results, although work on verification of Ehrlich's predictions[4] of the on-axis performance of microwave mirrors was initiated by Gordon M. Russell[5] in 1951 for a master's thesis. In particular, the limitations of an antenna-reflector combination have been neglected. The effect of misalignment of the reflector, variations from a plane surface, and the use of reflectors of rectangular shape instead of the more readily calculated elliptical shape should be investigated. Only the first of these problems is considered in this report.

Experimental verification of theoretical predictions of reflector performance has been obtained for both correct and incorrect alignment of a microwave antenna with the wave reflected by a plane, elliptical mirror. The theoretical analysis was obtained by an extension of the Fresnel-optical analogy employed by Ehrlich[4] in predicting the on-axis performance of a reflector-antenna combination. This method utilizes a graphical integration of the diffraction pattern from a circular aperture in an infinite, opaque sheet. The experimental results were obtained with an elliptical reflector designed to have a circular intercepting area at the angle of incidence and reflection.

Theoretical Results

An illustration of the aperture analogy used to calculate the magnitude and phase of the field-strength vector **E** at various points in a plane at a distance D from the aperture or reflector is shown in Fig. 1. The definitions of symbols to be used are also indicated. The radius of the aperture is a. The displacement from the axis is designated by r, but a normalized displacement Δ, which is the ratio r/a, will be adopted in order to present the results in normalized form for ready application to any geometrical configuration. The distance from the aperture or reflector will be d. The symbol d_f refers to the distance to the first Fresnel zone, and the normalized distance D is equal to d/d_f.

A. E. Harrison

The aperture is divided into circular zones of equal area, as shown in Fig. 1-a, to obtain the magnitude and phase of the **E** vector at different distances D along the axis of the aperture. The contributions from the different zones are added vectorially. A magnitude of unity is assumed for the $\mathbf{E}_0$ vector incident upon the mirror; therefore the calculation gives the magnitude of the **E** vector of the reflected wave relative to the magnitude of the ncident wave.

Zones with radii chosen to give the same total area for a complete circular zone as indicated in Fig. 1-b are used in computing the **E** vector at points off the axis. The contributions from each zone are modified in accordance with the reduced areas when the aperture does not intercept a complete zone. The **E** vector was determined in this manner for points up to 1.8 a from the axis. The resulting curves of the magnitude of the **E** vector at various normalized distances D from the reflector or aperture are plotted in Fig. 2. These patterns are similar to the diffraction patterns observed when light passes through a very small aperture. The first pattern corresponds to a dark spot in the center surrounded by a bright circular ring of light. The second pattern will be recognized as analogous to a bright central core of light surrounded by alternate dark and light rings.

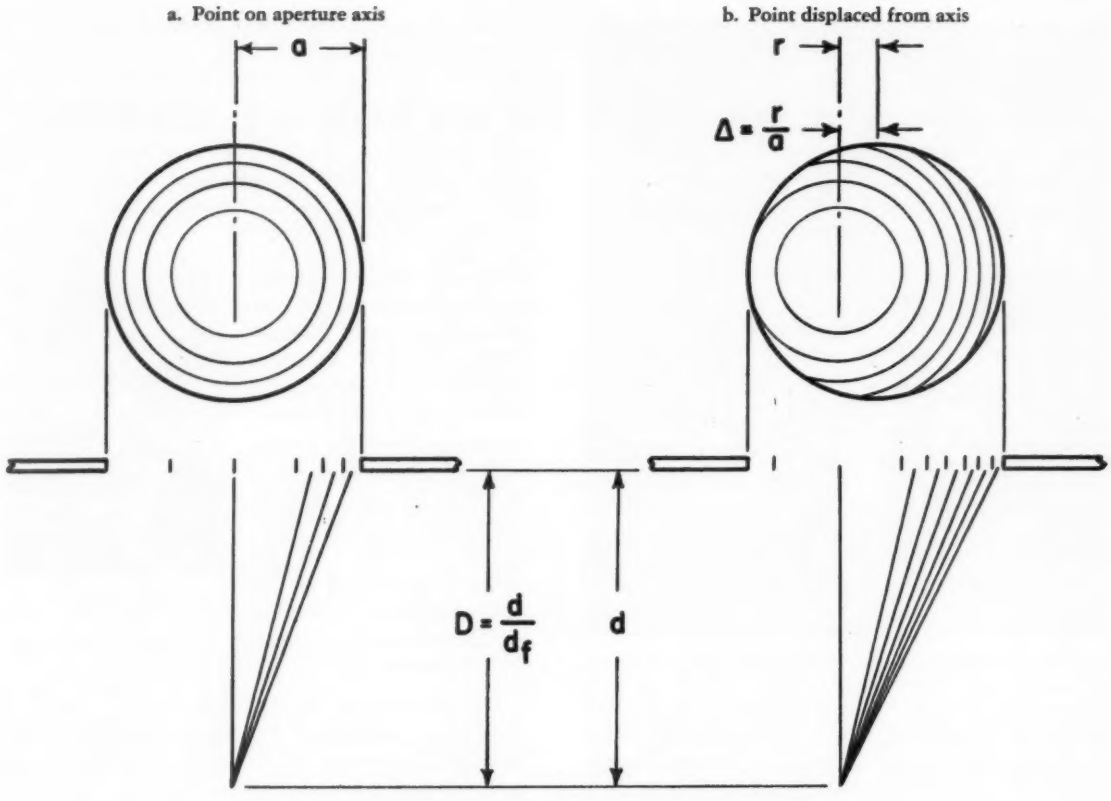


FIG. 1. OPTICAL APERTURE ANALOGY FOR A MICROWAVE MIRROR

The data in Fig. 2 must be converted into information on the power intercepted by a microwave antenna. Since a paraboloidal receiving antenna is considered, this conversion is accomplished by dividing the area under the reflector into circular zones of equal area concentric with the point corresponding to $\Delta = 0$. These "receiver" zones are similar to the zones in Fig. 1-a but extend beyond the limit of the aperture radius a to the maximum value of Δ in Fig. 2. The average value of the square of the magnitude of E over the nth zone (written $\overline{E_n^2}$) is determined for each receiver zone.

Each zone is assumed to have an area of unity. If the paraboloid is not on the axis of the aperture, the entire energy of some zones will not be intercepted. The per-unit value of the contribution of a zone (written z_n) is found by drawing the outline of the receiving "dish" over the receiver zone pattern described above. The value of z_n will be unity if an entire zone is intercepted, and less than unity for a fractional zone. The product of z_n and $\overline{E_n^2}$ gives the power contributed by the nth zone. These increments are summed for all zones intercepted by the dish at a particular location to obtain the total reflected power intercepted at that location of the dish. This process may be expressed by the relation,

$$\text{Reflected power intercepted} = \sum_{n=1}^{n=N} \overline{E_n^2} z_n . \quad (1)$$

Since the magnitude of the incident wave $\mathbf{E}_0$ is taken as unity, then $\overline{E_0^2}$ is unity. Hence the total power intercepted when the receiving dish is exposed directly to the incident wave from the transmitter is merely the total area of the dish (designated A_R) expressed in terms of zones. This relation may be written

$$\text{Incident power intercepted} = A_R . \quad (2)$$

The relative gain is the ratio of the reflected power intercepted to the incident power intercepted, or

$$\text{Relative gain} = \frac{\sum_{n=1}^{n=N} \overline{E_n^2} z_n}{A_R} . \quad (3)$$

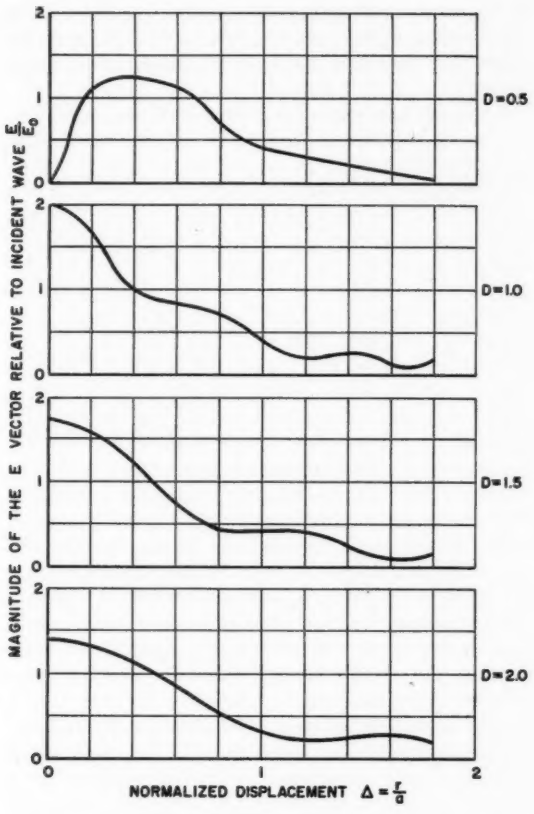


FIG. 2. DIFFRACTION PATTERNS AT VARIOUS DISTANCES

Variations in the phase of the contributions from the different zones have been ignored in this analysis. This amounts to assuming that the receiving dish has the characteristics of a black body in that it reflects none of the incident energy. An additional assumption is that the receiving dish has equal response over its entire area. Ehrlich[4] made these assumptions in his paper, and they were adopted in this investigation in order to simplify the calculations. Their validity will be discussed in a later portion of this paper when the experimental results are compared to the theoretical predictions.

The problem of presenting the information on relative gain in the most useful form is complicated by the fact that the off-axis gain depends on the wavelength λ of the microwave signals as well as on the angular adjustment of the reflector and the two antennas. If the data are presented with the deviation angle as a parameter, then a separate set of curves will be required for each different wavelength.

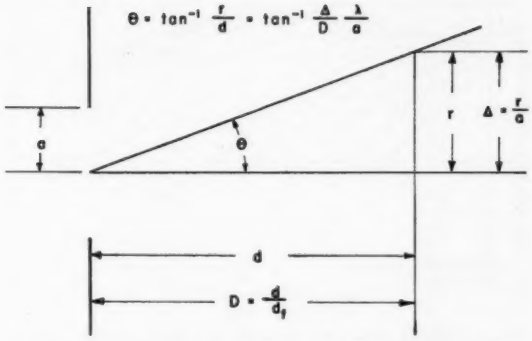


FIG. 3. ANGULAR RELATIONS FOR OFF-AXIS OPERATION

Reference to Fig. 2 will indicate that the gain for a normalized displacement Δ at a normalized distance D will be the same, regardless of the magnitude of a, if the radius R of the paraboloid is changed so that R/a remains constant. Therefore it will be desirable to plot the data with Δ and D as parameters and relate these parameters to the angular deviation.

Figure 3 illustrates the relationships between the actual distances, the normalized distances, and the angular deviation. It will be convenient to deal with the angular deviation θ of the receiver from the axis of reflection, since the mirror and transmitter remained fixed during the tests, and only the receiver was moved. This choice of θ corresponds to a misalignment of the reflector of $\theta/2$ in the practical case where the transmitter and receiver are fixed.

According to Fig. 3, the deviation angle θ may be expressed as follows:

$$\tan\theta = \frac{r}{d}. \tag{4}$$

By definition, d_f, D, and Δ are given by

$$d_f = \frac{a^2}{\lambda}, \tag{5}$$

$$d = Dd_f, \tag{6}$$

$$r = \Delta a. \tag{7}$$

Substituting Eq (5), (6), and (7) into Eq (4) gives

$$\tan\theta = \frac{\Delta a}{Dd_f} = \frac{\Delta}{D}\frac{\lambda}{a}, \tag{8}$$

$$\theta = \tan^{-1}\frac{\Delta}{D}\frac{\lambda}{a}. \tag{9}$$

For small values of θ the following approximation is valid:

$$\theta \cong \tan\theta = \frac{\Delta}{D}\frac{\lambda}{a} \text{ (in radians)}, \tag{10}$$

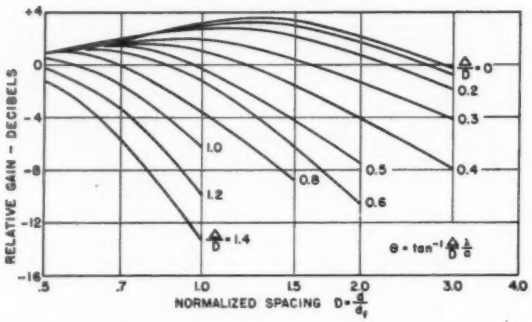


FIG. 4. NORMALIZED PERFORMANCE CURVES FOR R/a=0.375

$$\theta \cong \frac{180}{\pi} \frac{\Delta}{D} \frac{\lambda}{a} \quad \text{(in degrees)}. \qquad (11)$$

Curves of gain versus displacement with Δ/D as a parameter are plotted in Fig. 4 for a dish-to-mirror ratio R/a of 0.375. The parameter Δ/D may be converted to an angle θ by the use of Eq (9), (10), and (11). The exact relation given by Eq (9) will seldom be needed since angles greater than 10° could hardly be tolerated in practice. In most cases interpolation between the curves of Fig. 4 will be satisfactory if specific angles of deviation are required.

Experimental Procedure

A mirror and a movable cart holding the receiving equipment were set up on the roof of the Electrical Engineering Building at the University of Washington with the center of the receiving paraboloid at the same level as the center of the mirror. The transmitter was located at a distance of approximately 1,500 ft, at the same level as the center of the mirror. The vertical location of the transmitter was checked with a surveyor's level.

A transit set up at the mirror position was used to locate the proper horizontal position of the transmitter and to lay out radial lines along which the receiver cart was to be moved. The radials were spray-painted on the roof. At the same time, the transit was used to lay out on the roof a line representing the plane of the mirror which would result in the desired angles of incidence and reflection to produce maximum gain along the zero-degree radial already laid out along the roof.

The transit was then moved to a point along the mirror-plane line, and the mirror was placed in position. The mirror was adjusted so that its left and right edges appeared to merge when viewed through the transit. The mirror was made vertical by dipping the transit and adjusting the mirror until the top and bottom of the mirror lined up with the vertical cross hair. The mirror alignment was checked by setting up the receiver at approximately twice the first Fresnel distance to see that the maximum field intensity apparently occurred at the zero-degree radial as it should.

Since the theoretical data were not then available, it was not realized at the time the experimental work was performed that the mirror requires very critical alignment. It is entirely possible that adjusting the mirror until the right and left edge appear to merge may result in a misalignment of a large fraction of a degree. Moreover, the alignment check by a field-intensity measurement is not very accurate since movement of the cart necessitated readjustment of the receiving dish and attenuator settings, and the accuracy of reproducing these readings is approximately ±1 db. Reference to the relative gain-versus-distance curves shows that at twice the first Fresnel distance (approximately 80 ft) an error of 1 db corresponds to a misalignment of 0.5°.

Comparison of the experimental and theoretical data indicates that much more care should be exercised in the original alignment of the mirror. An optical mirror might be used to temporarily replace the microwave reflector, with a bright light placed at the transmitter location. Then with a transit at a point along the 0° receiver radial it should be possible to align the mirror with the accuracy required for this investigation.

The experimental data were obtained by comparing the incident wave, intercepted by aiming the dish directly at the transmitter, with the wave reflected from the microwave mirror. A calibrated attenuator in the waveguide between the antenna and the crystal mixer permitted the receiver to be operated with a signal-strength meter at the same "standard reading" for all tests. In this manner the signal-strength meter served only as a comparison device, and the gain was calculated from the difference in attenuator settings. After the measurements along a given radial line had been completed, the receiving dish was aimed at the transmitter again as a check on the field strength and the constancy of the receiver gain.

Results and Discussion

Relative gain curves have been replotted in Fig. 5 as a function of reflector-antenna spacing in feet, with angular deviation as a parameter, for a wavelength of 3 cm, a 4-ft reflector, and an 18-in. dish. The solid curves indicate the theoretical gain while the broken lines indicate the experimental results. Reference to the curves indicates that the experimental curve for the 0° radial (on axis) is lower than that predicted by theory, but that all other experimental curves are higher than the corresponding theoretical curves. Further inspection of the curves indicates that the experimental curves are of the proper shape and are located in approximately the

positions that would correspond to theoretical curves for —0.5°, 1.5°, 3.5°, and 5.5°. For this reason, curves indicating the theoretical response for —0.5°, 1.5°, 3.5°, and 5.5° are plotted in Fig. 6 for comparison with experimental readings for the 0°, 2°, 4°, and 6° radials.

The experimental points lie along these adjusted response curves with no more than a normal scatter. The assumption that the mirror was misaligned by 0.25°, corresponding to an error of 0.5° in θ, also explains why the experimental response is low for the 0° radial and high for the other radials. In view of the procedure used in aligning the mirror, the assumption that the mirror was misaligned by 0.25° is reasonable, and the experimental verification of the Fresnel-optical analogy prediction is considered quite satisfactory.

The necessity for accurate alignment at large spacings is evident from the curves of Fig. 4. The deviation Δ/D may be as high as 0.8 with no loss in gain at a normalized spacing D of 0.5. This value of deviation corresponds to an angle of 2.4° for a 4-ft reflector and a wavelength of 3 cm. As the spacing between the reflector and the dish is increased, the alignment, in terms of angle, becomes increasingly critical. At a spacing of three times the distance to the first Fresnel zone (D=3.0), the gain is reduced by 3 db when the misalignment corresponds to an angle of only 0.7°.

The reason for the necessity of such critical alignment at large distances d from the reflector may best be understood by reference to the curves in Fig. 2, which show the magnitude of the **E** vector versus displacement from the axis. These curves show that the major portion of the reflected energy is distributed over an area of the same relative magnitude as that of the mirror. Although this area does become somewhat larger with increasing d, it does not change appreciably. Since the size of the area containing most of the energy is relatively constant, the angle intercepted by this area becomes smaller as the receiving dish is moved away from the reflector. Thus the alignment in terms of angle becomes progressively more critical as the spacing between dish and reflector is increased.

One conclusion from these data is that a reflector introduces a "directivity" in a microwave beam which increases as the distance between the reflector and the antenna is increased. This apparent directivity is not accompanied by a tremendous increase in gain, as is the case with highly directive antennas. Some gain is possible with a reflector at the first Fresnel-zone spacing, but in general the difficulties in alignment are compensated only by the advantages of using a passive reflector instead of a microwave transmitter at some inconvenient location.

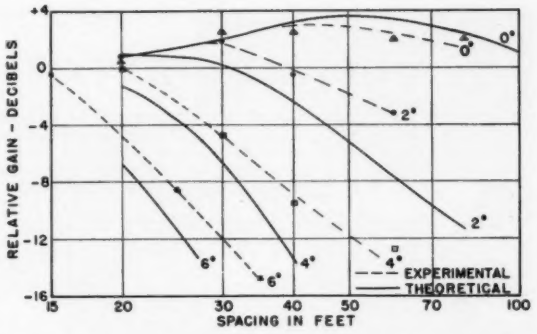


FIG. 5. COMPARISON OF THEORETICAL AND EXPERIMENTAL RESULTS FOR A 4-FT MIRROR AND AN 18-IN. PARABOLOID

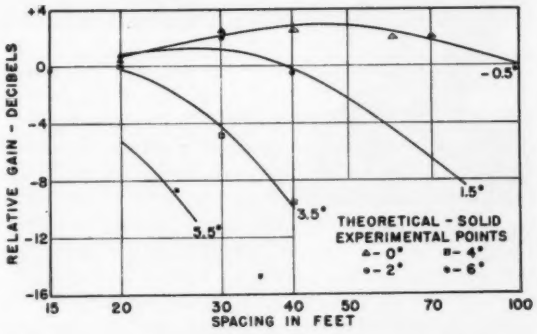


FIG. 6. COMPARISON OF THEORETICAL AND EXPERIMENTAL RESULTS FOR A 4-FT MIRROR AND AN 18-IN. PARABOLOID (Assuming 0.5° error in experimental angle)

Good agreement between the experimental results and theoretical predictions suggests that neglecting the variations in the phase of the contributions from the different zones, mentioned in the paragraph following Eq (3), does not limit the usefulness of the predictions. Difficulties were anticipated, particularly for the larger deviations where the amplitude is reduced and the phase is varying rapidly. Apparently the nonuniform response of the area of the paraboloid and the effects of phase variation can be ignored.

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AN EVALUATION OF REFLECTANCE READINGS IN ATMOSPHERIC POLLUTION STUDIES*

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RICHARD G. TYLER
Professor of Sanitary Engineering

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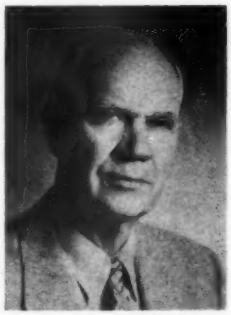
K. L. Lamb

During 1951-52, the Environmental Research Laboratory of the University of Washington undertook an air-pollution survey for the city of Seattle, at the request of the City Engineering Department. As part of this study, an attempt was made to quantitate the results of reflectance readings of the aerosols, or suspended solids, removed from the air, by drawing known volumes through a disc of Number Four Whatman filter paper in a Seitz filter with a vacuum pump (Fig. 1). The reflectance reading is a photometric measurement of the light reflected from the surface of the filter disc when compared with that reflected from magnesium oxide. It is thus a measure of whiteness of the sample, with this standard taken as 100 per cent. A blank disc of Number Four Whatman filter paper has a whiteness of 75 ± 1 per cent on this scale.

The fact that many attempts to determine the weight of the material collected by the Seitz filter failed to secure reproduceable values because of variables associated with the drying of the paper and samples, suggested that the reflectance determination would be preferable if a method for its quantitation could be worked out. To do this required a means of accurately determining the weight of the samples which were to be compared with reflectance determinations on filter paper. A "medium grade" fritted glass filter was therefore selected for collecting samples in parallel with the filter-paper samples. To test the efficacy of the glass filter, filter paper was placed under the glass filter for a run of carbon, which would discolor the paper should any pass through the glass. No discoloration occurred, indicating that no material was passing the glass that could be caught by the paper. Parallel tests were then run on samples collected by the two filter media. The glass filter could be heated, dried in an oven and cooled in a desiccator, and the solids captured from the smoke could be compared with the reflectance readings of the Seitz filter discs.

Wm. Maske



R. G. Tyler

To calibrate the glass filter required the production of a smoke in the laboratory that would be comparable to that found locally in the atmosphere. A mixture of alcohol and benzene, 50 per cent of each by volume, was found to produce particles of carbon that approximated those of the atmosphere. It was also desirable to be able to control the flame with enough accuracy so that the range of blackness observed on the paper samples could be reproduced and weighed on the glass filter. All types of burners used, however, gave too dense a smoke for getting the lighter shades needed for calibration purposes. The method finally successful in limiting the quantity of carbon to the desired amounts was to bubble commercial gas through the mixture in a flask ahead of the pilot flame which was used for better control. The Seitz filter head also required shaping so that it could take all of the smoke produced (Fig. 1). Comparison of this smoke with natural smokes collected on the Seitz filter discs at the various sampling stations was made with the aid of the electron microscope. Figure 2 shows that the fines in the air sample are of approximately the size and nature of those in the synthetic sample. Figure 3 shows the relationship of the weight of the samples to the reflectance

*Condensed from the thesis of K. L. Lamb submitted for the degree of M.S. in Civil Engineering, 1952.

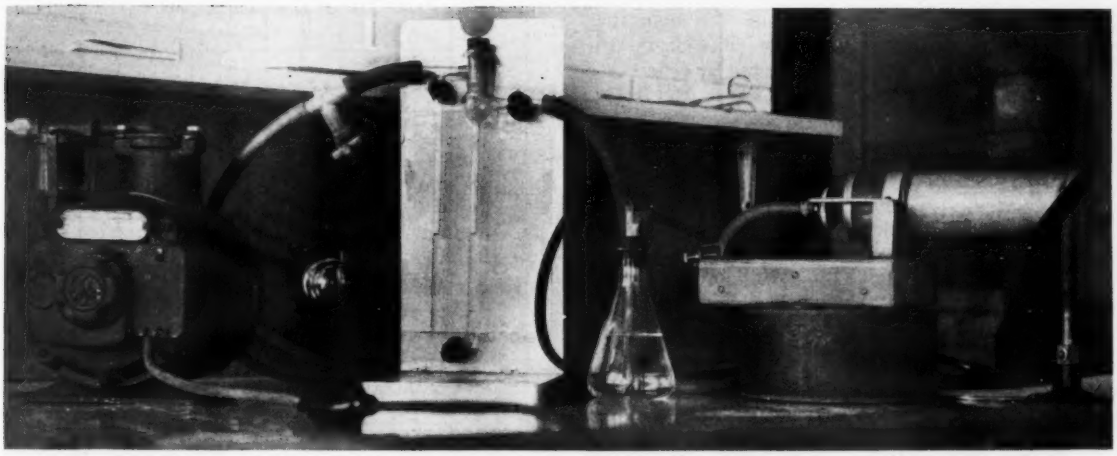
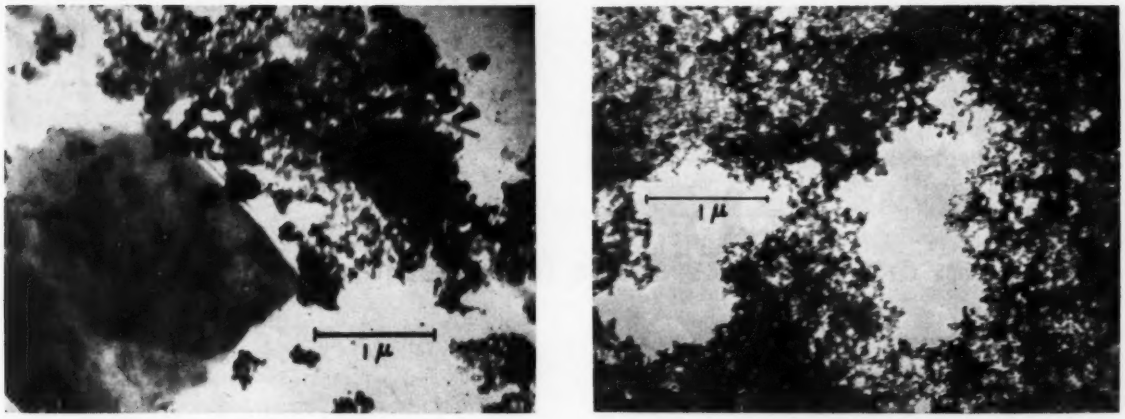


FIG. 1. APPARATUS FOR COLLECTING AEROSOLS ON FILTER
(Pump, manometer, and Seitz filter head)



a. Actual city dust*

b. Synthetic dust

FIG. 2. PHOTOMICROGRAPHS (×20,000) SHOWING GENERAL SIMILARITY OF ACTUAL CITY DUST AND SYNTHETIC DUST

readings. On some of the tests in the field, an electrostatic precipitator was used in parallel with the Seitz filter. The weights obtained by it ran from 0.003 to 0.008 g for 24 hours. With the fritted glass filter, total weights of 0.001 g for a 3-hour sample, 0.0031 g for 5-hours, and 0.0039 g for a 6-hour sample (i.e., the same general magnitude as the precipitator catch) were obtained. It is possible that the fritted glass may be as satisfactory for weight determinations as the electrostatic precipitator, besides being much simpler to use. The difficulty of cleaning the glass, however, is a handicap to its use.

The glass filter when run in parallel with the paper filter was found to have a higher catch than the paper filter, indicating a greater efficiency. It was used in the laboratory to catch a dust produced by grinding materials similar to city dust (other than carbon), such as diatomaceous earth, fuller's earth, celite, and bentonite. Even with a weight as large as 0.01 g the reflectance reading was not changed. It was concluded, therefore, that the reflectance reading primarily measured the carbon in the atmosphere, while the total weight should check or correlate with the data obtained by the electrostatic precipitator.

The following conclusions may be drawn from this study:

1. The reflectance reading, as commonly used, is not applicable to quantitative analyses.
2. The reflectance reading can be used with the aid of a curve such as was developed in this

*Note: The large particle in Fig. 2-a is clay.

paper (Fig. 3), to determine the quantities of carbon in the atmosphere since it is primarily the carbon that is indicated by reflectance readings.

3. The particles other than carbon account for the major part of the weight. In no case did the weight of carbon exceed 0.0004 g as compared with 0.008 g of total weight (5 per cent).
4. The process of cleaning the glass filter will probably limit its use until the filter can be made more cheaply, but it is a useful tool for determining both the carbon (through reflectance) and the total weight of aerosols present. The glass filter also should undoubtedly prove useful in taking spot readings or making a rapid and relatively rough survey of a community to determine the distribution and general magnitude of the air-pollution problem from particulate matter.
5. The paper filter, operating in parallel with the electrostatic precipitator, will also measure both carbon and total weight of aerosols, or, used alone, will determine the smoke fraction of the aerosols, which is sometimes a major problem.

The authors hope to continue experiments with the glass filter in field studies in order to formulate more definite methods for its use.

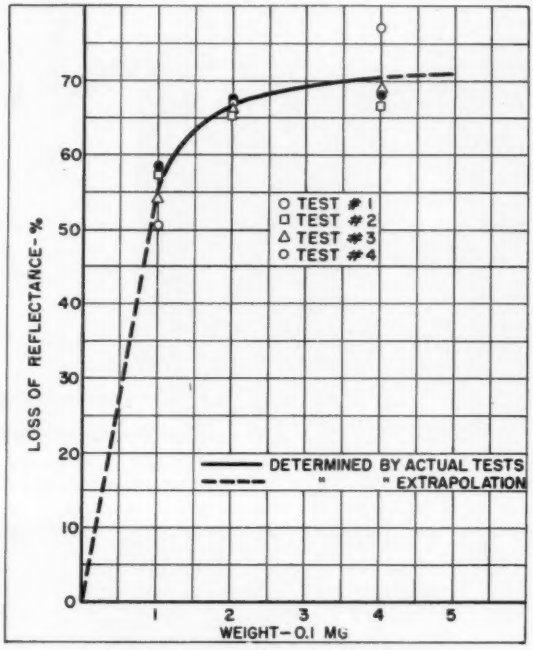


FIG. 3. STANDARD CURVE FOR CARBON
(Based on loss of reflectance vs. gain in weight)

Seismographic Evidence for Blasting Operations

DURING THE PAST THREE DECADES users of explosives have been faced with an increasingly important problem: ground vibration caused by blasting. In the heavily industrialized East the problem was recognized and remedial measures taken as early as the 1920's. Special techniques were developed for measuring and studying vibrations from blasting. As a result, extensive information has been accumulated on the nature of these vibrations and their effects on structures and on the ground through which they pass. In addition to this, the effects of airborne concussion have been investigated. This work has established that normal commercial blasting operations do not cause vibration or concussion of damaging intensity at ordinary distances.

In spite of this, blasters are often faced with serious operational problems in the form of vibration or concussion complaints. These protests range from mere nuisances to major damage claims. Political pressure may be brought to bear to impose unreasonable limitations or restraints on quarrying or excavation operations.

The problem of blasting vibration can usually be handled in two ways. If trouble is anticipated by an explosive user he can call in a vibration engineering firm to monitor his operations and ascertain the maximum amounts of explosives that may safely be shot at any location, recommend delay blasting, or suggest other remedial measures. This is exactly analogous to buying insurance; claims may be referred to the vibration consultant who is armed to dispose of them. The other situation is the one in which the consultant is called in to make measurements after claims have been filed. If no restrainer has been placed on the operation, readings may be taken as blasting continues. On the basis of the measurements the vibration engineer can analyze the damage potentials, compute the safety factors, and determine the liability of the blaster. Almost always, the results of such an investigation produce positive results showing that ordinary operations at normal distances produce no damaging effects to structures. The only method of proof, however, is with a seismograph and a scientific analysis.

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An Investigation of Pollution in the Yakima River Basin*

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R. O. Sylvester

During the summer of 1951, the Washington State Pollution Control Commission engaged the services of an impartial group to conduct a comprehensive survey of the Yakima River, its tributaries, irrigation canals, and return-flow drains for the purpose of determining the existing water quality in the Yakima River Basin, the sources of water pollutants, and their subsequent effect on water quality. The survey period included the main portion of the irrigation season and period of low stream flows.

Milton Westin, field engineer of the Commission, J. T. Suzuki and M. G. Dailey, recent engineering graduates of the University, and the writer, as supervisor of the project, made up the surveying party. Cooperating with the survey group by furnishing information and facilities, were the cities of Ellensburg, Yakima, Union Gap, and Sunnyside, the Kittitas County Hospital, the Bureau of Reclamation, the Geological Survey and Indian Service, the Benton, Yakima, and Kittitas County engineers, the State and the Yakima County and Kittitas County Health Departments, the U. S. Public Health Service, the Pacific Northwest Drainage Basin Office, the University's Civil Engineering Department, and various basin industries.

PURPOSE

The Yakima River and its tributaries drain some 5,970 square miles, of which approximately 1,000 square miles are potentially irrigable. The economy of the basin and the welfare of its inhabitants is primarily dependent upon the use of the water of the river system for irrigation and water supply. The disposal of unwanted waste of the area into the system has interfered with these and other uses which may be made of these waters.

The polluted condition of the river, tributaries, irrigation canals, and drains has been a subject of concern since regional development first started on a large scale shortly after the turn of the century. Numerous investigations, but mostly those of a limited nature, have been conducted to determine the condition of the Yakima River.

There has long been a definite need for a more comprehensive study of the river and especially of the several irrigation systems. The purpose of the study herein reported was to obtain further information on which to base a sound and constructive program of pollution control for the basin. The following items were included in this study:

1. Sources of pollution in the Yakima River and tributaries, together with their quantity and characteristics.
2. Chemical, bacteriological, and physical condition of the river, its tributaries, irrigation canals, and return-flow drains during the height of the irrigating season, June 15 to September 1.
3. Effect of return irrigation flow and water from tributaries on characteristics of the Yakima River.
4. Capability of the river to assimilate pollution.
5. Change in water conditions during consecutive 24-hour periods and effect of algae and aquatic plants on dissolved oxygen content and other conditions.
6. Any notable change in river conditions since previous surveys.

The results of this survey which covered the period June 21 to August 29, are indicative of conditions during the most critical portion of the year.

WATER USAGE

The Yakima River and its major tributaries are controlled streams, with control being exercised by six impounding reservoirs storing a total of over 1,000,000 acre-feet of water. The mean-annual-flow of the Yakima River near its mouth at Kiona is 3,921 cfs, with an annual maximum flow of 6,260 cfs from April 1 to about October 25. Low flows are experienced during the irrigation season just below the Sunnyside diversion dam where flows may be reduced to 60 cfs or less.

The Yakima River Basin surface waters have the following principal uses: *(a)* irrigation and stock

*Condensed from Technical Bulletin No. 9. WSPCC, Summer, 1951, Olympia, Washington.

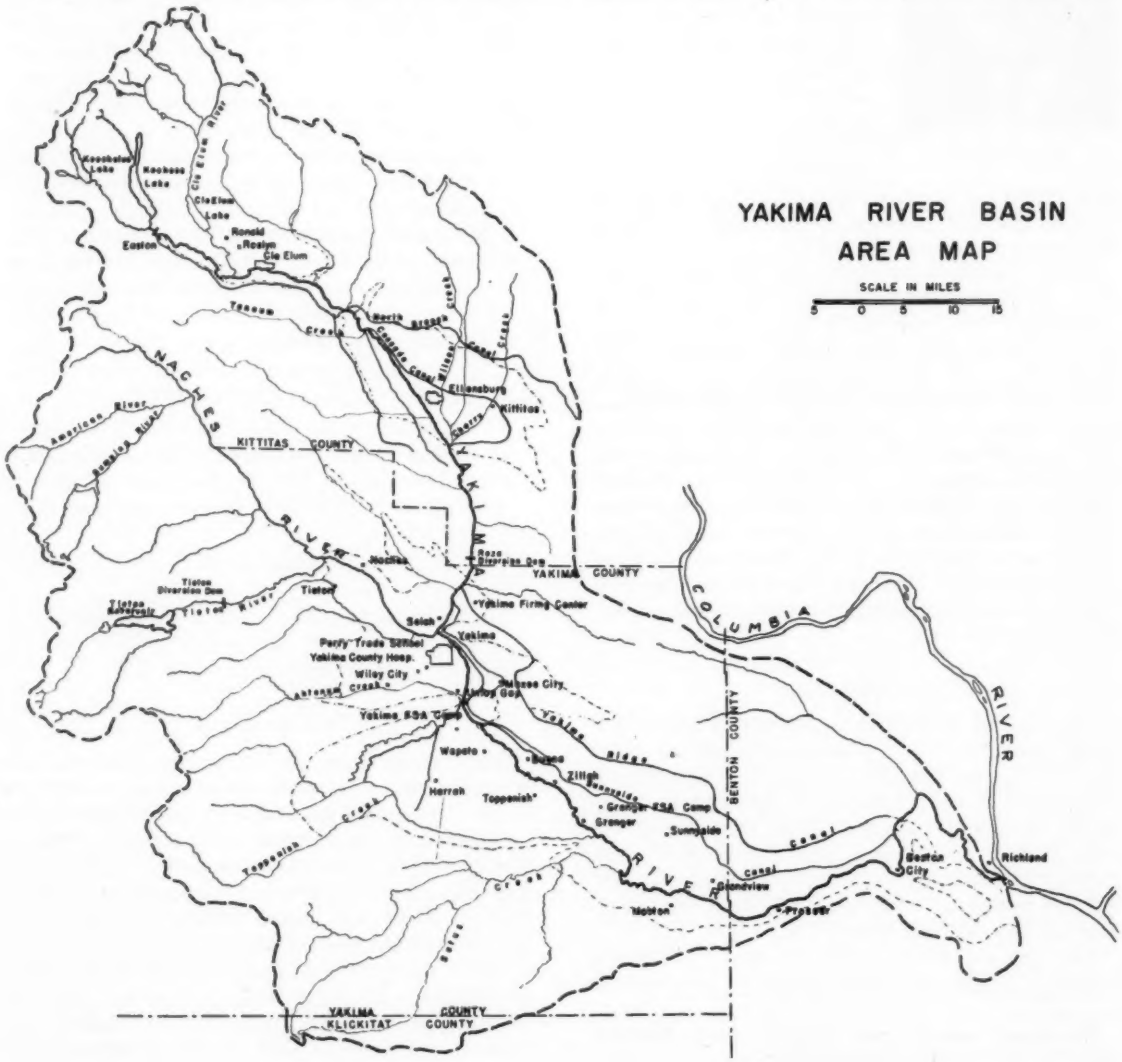
watering, *(b)* fisheries, *(c)* power, *(d)* municipal water supply, *(e)* recreation, and *(f)* industry.

a) Irrigation is the principal use of basin surface water. The Yakima Chamber of Commerce in 1950 reported the total irrigable area and proposed projects amounted to 621,062 acres; the actual irrigated area, in 1946, was 439,300.

b) The U. S. Fish and Wild Life Service has reported the Yakima River Basin to have a commercial fishery value approaching $100,000 annually and a sport fishery value exceeding $300,000 annually. The river system was believed to have been a tremendous producer of anadromous fish prior to the settling of the basin. Since the coming of the white man, the fishery has declined because of diversion dams, unscreened diversions, and low flows. However, the stream is still an important salmon-producing tributary to the Columbia River, and pollution should not be allowed to lessen its usefulness.

c) Water-power development has been subservient, generally, to irrigation demands. Aside from power drops on the irrigation canals, there are only four small hydroelectric plants located on the Yakima and Naches Rivers, having a combined generating capacity of about 10,000 kilowatts.

d) The majority of the smaller communities in the river basin obtain their water supply from deep drilled wells. However, ground waters in certain areas are poor in quality and unsatisfactory as domestic supplies due to mineral and sulfur compounds



and gases. Approximately 50,000 persons residing in the cities of Yakima, Cle Elum, Ellensburg, Roslyn, and Easton obtain all or a portion of their water from surface sources where the intakes are above any present significant source of pollution.

Large portions of the Tieton Irrigation Project area do not have available ground water for domestic water supply and must rely upon the Tieton Canal system to fill their water cisterns. Special cistern-fill runs are made (canals otherwise would be dry) in the latter part of November and February, depending upon ice conditions. A significant percentage of farmers in the Roza Irrigation Project use irrigation water to fill cisterns for domestic use.

e) Bathing and swimming have been observed in many of the streams and irrigation canal branches. Sport fishing is prevalent throughout the entire basin but is most common in the upper reaches of the streams. Many summer homes are located on national forest land in the upper Naches River system.

f) The increasing use of surface water by industry in the basin is due to the poor quality of ground supplies. Most industries obtain their water supplies from municipalities or from their own wells.

Sources of Pollution

Community Wastes

Twenty-two municipalities, institutions, or other population centers in the Yakima River Valley have sewer systems, with 18 having sewage-treatment plants, while the remaining four discharge their raw sewage into the watercourses of the valley.

Only nine of the communities have facilities to provide adequate sewage treatment, with the other 13 offering an inadequate degree of treatment due to overload from industries, infiltration, or lack of facilities to provide the proper degree of treatment. Deficiencies in operation have been noted in many of the sewage and industrial waste treatment facilities.

Chlorination as practiced in the Yakima River Valley is generally inadequate because chlorine is not applied in sufficient quantities or under control such as to produce a proper bacterial reduction in the sewage-treatment plant effluents. This factor, plus the lack of any chlorination in several communities, including Yakima the largest city, results in undesirable bacterial contamination of the waters in the Yakima River Basin.*

Industrial Wastes

About 33 known industries with significant amounts of organic and inorganic wastes have separate outlets into the rivers and streams of the Yakima River Basin, and, in addition, over 30 industries discharge their wastes into municipal sewer systems. Meat and food-processing plants contribute the greatest amount of organic pollution. Eighteen of the industries with outlets direct to the river meet the minimum requirements of the Pollution Control Commission on waste prevention, with 11 industries requiring increased waste-prevention facilities, and the status of four being undetermined. Some industries satisfying the minimum requirements have not necessarily fulfilled their obligations on the matter of waste disposal inasmuch as they discharge to small streams or into sloughs where the pollution load causes undesirable conditions. These industries should provide additional facilities for waste prevention and treatment over and above the minimum requirements.

Return Flows (Drains)

A very important feature of the Yakima River as concerns its flow and chemical quality is the effect of the return irrigation flows. The Yakima River flow below the Sunnyside Canal diversion at Parker consists almost entirely of return flows made up of irrigation ground-water seepage into the drains and the river itself. As an example, the average flow in the Yakima River below the Sunnyside diversion during the week of July 8 to 14, 1951, was 150 cfs, while 70 river miles downstream at Kiona, the average flow was 1,720 cfs. There are no tributaries of any significance in this river stretch except for the return flows during the irrigation season.

The majority of the drains carry return water with chemical and physical properties inferior to those of the river, thus producing a polluting effect. Some of the drains carry bacterial contamination from sewage.

Refuse

Direct dumping of municipal and private refuse (non-liquid wastes) into basin waters has been abated in almost all instances.

Survey Procedure

Eighty-three observation stations were established on the Yakima River, its tributaries, principal irrigation canals, and return-flow drains. These stations were located with the idea of obtaining an average picture of water conditions prevailing during the height of the irrigation season. Twenty-five of these stations were primary stations (observed once weekly) and the remainder were secondary stations (observed, usually, every two weeks). A few stations were established only for limited specific local information.

(Continued on page 31)

*Since the survey was made, the city of Yakima has taken effective steps toward correcting this condition.

USE OF BASE-FLOW INCREASE IN FLOOD PREDICTION

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Research Engineer, Department of Civil Engineering

DURING THE WRITER'S RECENT STUDIES in flood prediction methods, the need for an accurate means of predicting base-flow increase became apparent. Under the sponsorship of the Civil Engineering Department and supervision of Professor T. H. Campbell, and with the assistance of Ernest C. Pogge, some time was directed toward the solution of this problem.

To determine flood-flow distribution, it is necessary to construct a hydrograph of the predicted flow on a suitable base line which can be defined as a demarcation between the flow attributable to ground water during the period and the surface storm runoff.

A simple method would be to construct the derived hydrograph on a horizontal line representing base flow at the start of the runoff period. This method, however, gives a very large error in the latter portion of the storm period even though the distribution graph is correct. An alternate method involving construction of the derived hydrograph with the base-flow depletion curve used as a base, while quite acceptable on watersheds where a distribution graph is readily obtainable, is not practical on a watershed where the runoff functions are exceedingly complex. Therefore this method was also rejected.

The example of a typical storm from a given watershed, with conditions as shown in Fig. 1, was selected as a starting point. The preliminary problem, i.e., locating the termination of the surface runoff period, was approached by constructing the storm hydrograph and the base-flow depletion hydrograph for the period, and dividing the storm hydrograph into equal time intervals. If the runoff volume above base flow for each time period is computed and compared with the volume for the preceding and following time periods, a time interval will be found beyond which the rate of change of volume increments will vary at a constant rate. The first time unit beyond this point is the termination of surface storm runoff. Line AB in Fig. 1 represents this termination.

The initial ordinate of flow in the new depletion period is the increase in base flow that has been derived from the storm under study. The increase in this ordinate of flow will be known as ΔBF in this paper.

The next objective was to determine a method for estimating ΔBF at some time near the start of the storm period, as soon as the rainfall is known.

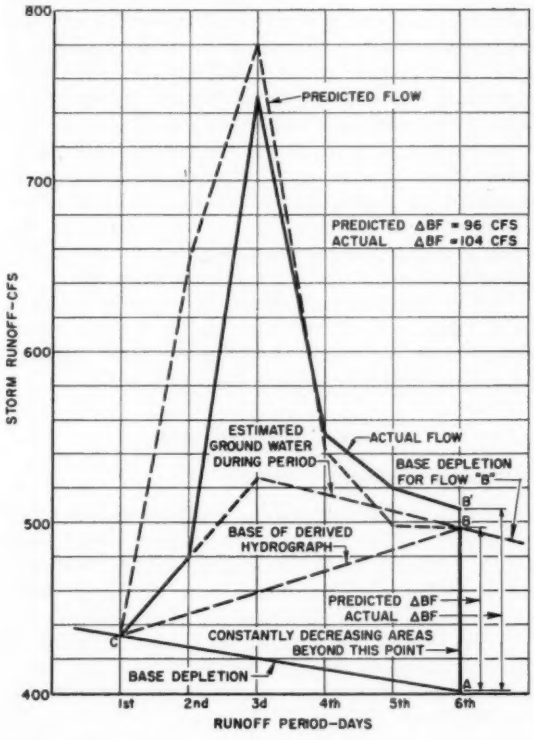

FIG. 1. HYDROGRAPH FOR PREDICTION OF A GIVEN FLOOD
Rainfall 1st day=0.37 in.
Rainfall 2nd day=0.44 in.
Ave. intensity (I)=0.405 in/day

The increase in the ordinate of flow, ΔBF, is a function of the ground-water condition of the watershed, the volume of the storm, and the intensity of the storm, I. To a lesser extent it is also a function of the amount of ground cover, condition of the ground cover, and quantity of surface storage; however, these latter variables are highly indeterminate in their effect upon ground-water increase.

For most years of record, it is impossible to determine the intensity in inch/hour of the storm, since hourly records are only a recent addition of most weather-bureau stations. However, it seems logical to assume that the vast majority of storms occurring during a given time of year would have the same

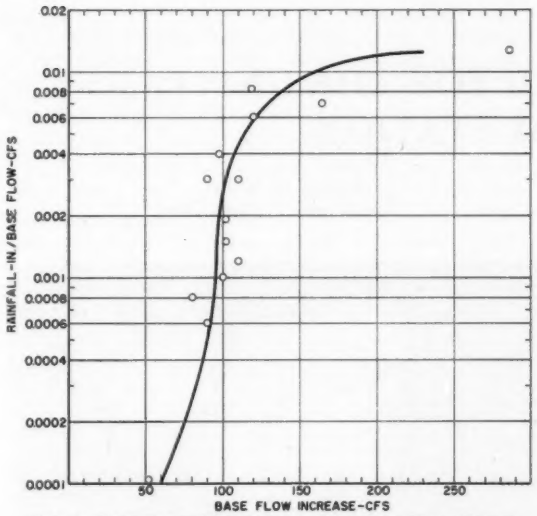

FIG. 2. BASE-FLOW INCREASE vs. RAINFALL/BASE FLOW
(For a given stream)

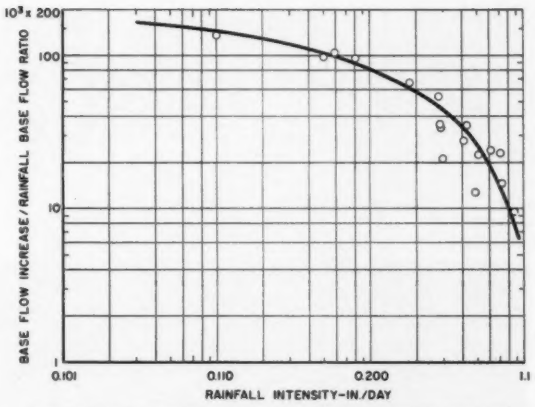

FIG. 3. RAINFALL INTENSITY vs. BASE-FLOW INCREASE/ RATIO TO BASE FLOW
(For the same stream represented in Fig. 2)

range of intensities. Extremely high- or low-intensity storms can be distinguished by introducing an additional parameter of inch/day. Actually, introducing the inch/day factor does not increase the accuracy of prediction in small-volume storms, but it does improve the forecasting of base-flow increase on storms of longer duration and large volume.

Because of ground-water and watershed conditions, a one-day storm and the first day of a many-day storm have a set of characteristics somewhat different from those of the subsequent days of the many-day storm.

In line with these observations, two graphs were constructed for a given stream to see if some correlation could be obtained and to check the validity of the basic assumptions. Figure 2 should be used in the prediction of base-flow increase in storms of less than 3 to 4 days duration. Figure 3 has been found to be more accurate for the day-by-day prediction in the case of longer storms with wide variations in intensity.

This method was then applied to the specific case shown in Fig. 1, as follows:

Duration of storm=2 days
Total rainfall=0.81 in.
Average intensity=0.405 inch/day
Base flow=432 cfs
RF/BF=0.0019.
ΔBF for Fig. 2=96 cfs
ΔBF for Fig. 3=75 cfs

Since the given storm of Fig. 1 was of less than three days duration, the value of ΔBF obtained from Fig. 2 was used. The derived hydrograph was then constructed from the rainfall information by determining the expected storm volume and distributing that volume by means of the applicable distribution graph.

An interesting sidelight that has been brought out in this study is that not only can the ΔBF be determined, but also the base flow during an entire storm period can be at least outlined, as shown in Fig. 1. This is done by projecting back from the plot of ΔBF the applicable base depletion curve to a point in the same time interval as the peak of surface runoff, and then drawing a straight line from the start of the storm period intersecting the base flow depletion at its peak.

ENGINEERS IN THE NEWS

E. C. S. RAO, Ceramic Engineering Fellow in the Station, took third prize in a nation-wide essay contest sponsored by the Ferro Co. of Cleveland with "A Theory of Adherence of Vitreous Enamels to Aluminum." He won fifth place in 1952. D. SUDER, senior in mineral engineering, took fifth prize this year.

B. D. OWENS, Instructor in Mechanical Engineering, read a paper on "Sequential Work Sampling" before the Pacific Northwest Conference on Quality Control, held on the campus May 8, 9.

J. I. MUELLER, Associate Professor of Mineral Engineering, after reading three papers before the meeting of the Pacific Northwest Branch of the IMME in Seattle, May 15-16 (reported elsewhere in this issue), presented his paper on "X-Ray Diffraction and Spectrographic Analysis of Ceramic Material," before the North American Philips Company X-Ray Diffraction School in New York, May 24, and later, at the meeting of the Ceramic Society of America, to which he also contributed "Industry-Sponsored Scholarships for Undergraduates in Ceramic Engineering."

A DATA-RECORDING SYSTEM FOR THE UNIVERSITY SEISMOLOGICAL STATION

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Instructor in Electrical Engineering

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Electronic Technician

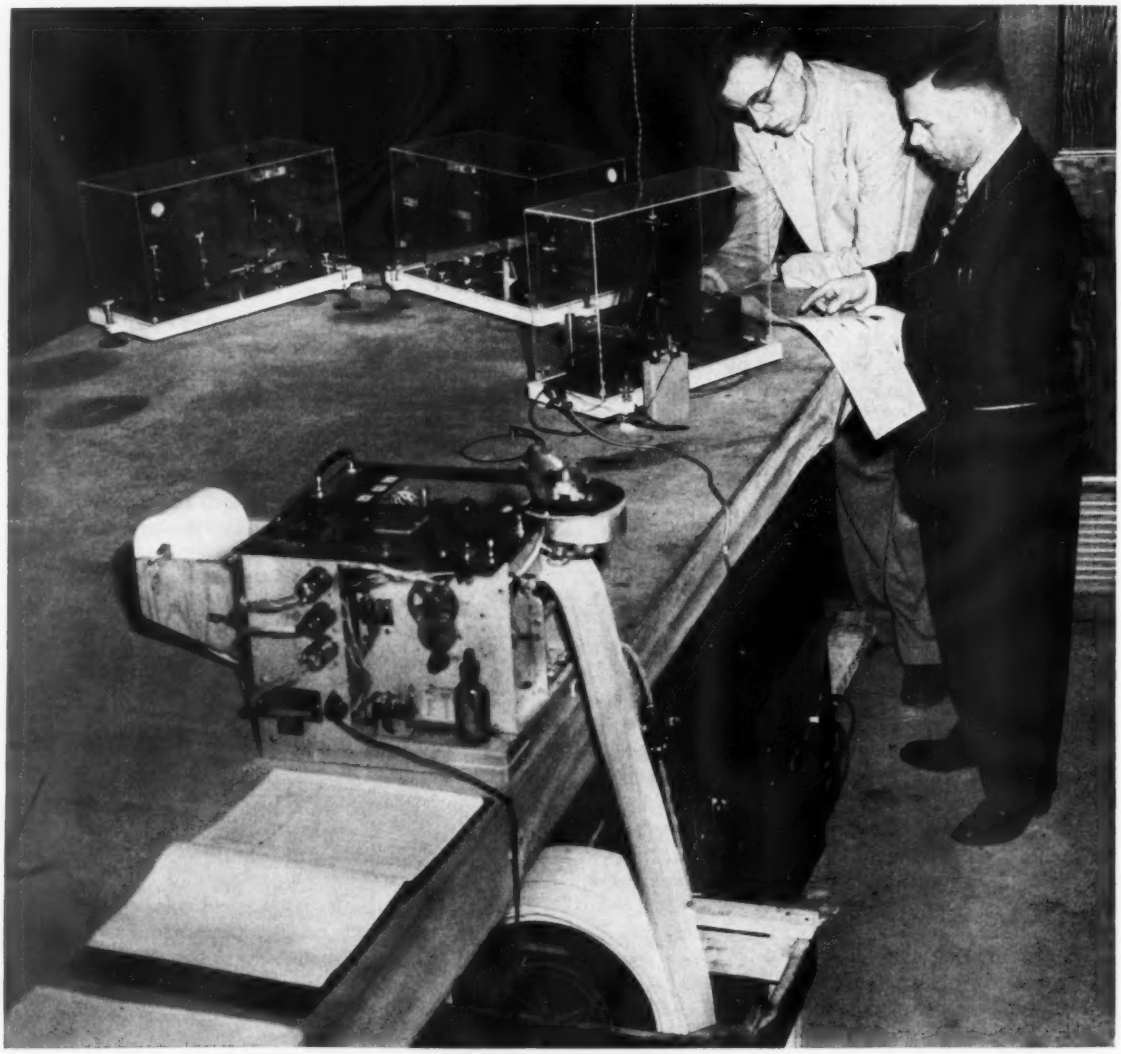

FIG. 1. SEISMIC DATA-RECORDING SYSTEM DEVISED BY AUTHORS (*l. to r.*) KOHL AND JACOBSEN
Background: Three Sprengnether seismic pick-up units
Foreground: Modified Sanborn recorder later replaced by model shown in Fig. 2
Under table, l. to r: Take-up reel, driver amplifier, converter amplifier

When the Department of Geology first established a seismological station at the University of Washington in 1949, its galvanometric-photographic system of recording data, though a type of system in general use, proved to have a number of disadvantages. These included the high paper cost, delay in obtaining information from current records, and bulkiness of the records, requiring considerable storage space. The galvanometric system was inherently a narrow band-pass system, necessitating two sets of seismometers in order to record the entire seismic spectrum. Lamp failures resulted in a loss of as much as a day's record.

Confronted with these problems, the Department of Geology requested the Electronic Group of the Engineering Experiment Station to develop a system to provide more accurate data recording at lower cost.

In developing a recording system for field stations,[1] multiple-channel, direct-inking recording oscillographs were used extensively and successfully during the first stages, although magnetic tape was ultimately adopted for field-station recording. When further investigation showed that the system could be improved to provide a higher quality of operation, the staff were asked to design equipment for the central station on the campus.

Requirements for the design of such a system included the following:

1. Two Sprengnether long-period horizontal seismometers, and one Sprengnether vertical seismometer, without modification, to provide a three-component seismic detection unit.
2. A three-channel amplifier to provide for amplification of frequencies from 0.05 cps to 10 cps, with a magnification ranging from 10 to 5,000. Since the output of the seismometer is proportional to frequency, the amplifier must provide an equalization of 100 to 1 over the desired frequency range.
3. A three-channel, direct-inking, recording oscillograph with paper speed of 1 mm per second and enough paper for five days of unattended recording.
4. For timing data, two pens to be mounted in the spaces between the channels. The timing data were to be arranged so that a seismographic record could be quickly and accurately inspected over a week's time, with accuracy of ± 1 second.

Figure 1 shows the equipment as finally set up, with the exception of the oscillograph which was later replaced by the one shown in Fig. 2.

Seismometer

The Sprengnether seismometer has a coil mounted on a horizontal pendulum[1] restricted so that the coil may move only in one plane. Its movement in a magnetic field generates tiny electromotive forces which

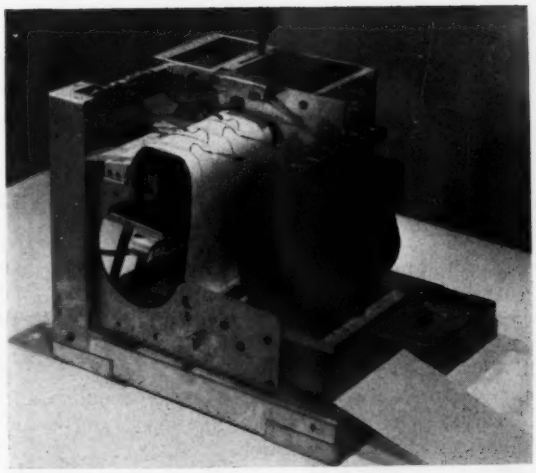

Fig. 2. Three-Channel Oscillograph Designed to Replace Unit Shown in Fig. 1

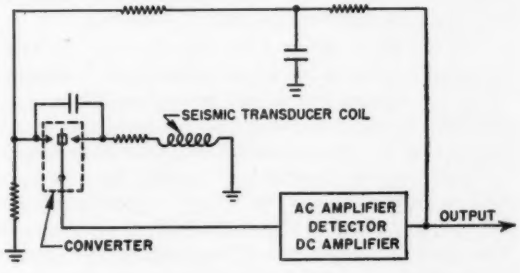

Fig. 3. Simplified Diagram of Seismic Amplifier

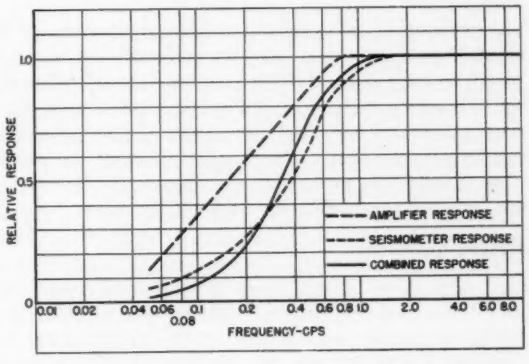

Fig. 4. Graph Showing Relative Responses of Amplifier and Seismometer

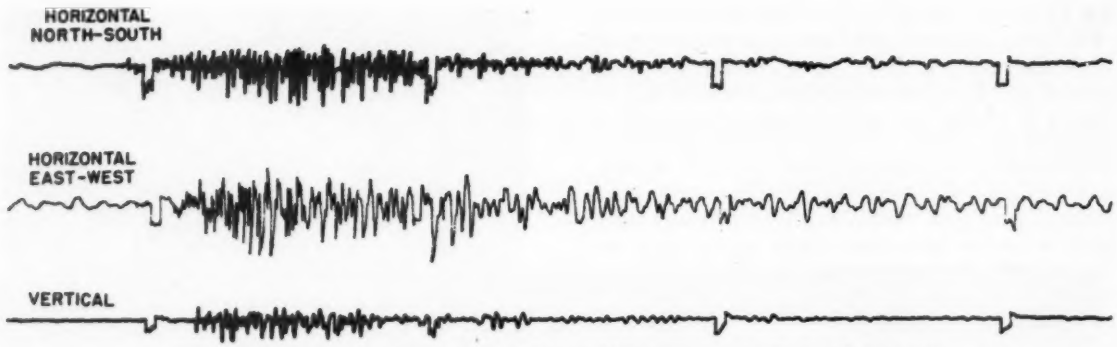

FIG. 5. TYPICAL RECORDING COVERING ABOUT 4 MINUTES TIME (Reduced about ¼)

are proportional to the velocity of the pendulum, the velocity being proportional to the displacement and frequency of the earth motion.

Amplifier

An experimental system was first assembled, using a Leeds and Northrup Direct Current Pre-amplifier[2] of the converter type to show the principles involved. This system showed such promise of stability and resolution that a three-channel converter[3] amplifier was designed and constructed.

The amplifier, using a 60-cycle Brown converter, is shown in Fig. 3. No input transformer is required since the seismic coil is not grounded. The voltage produced by the coil varies about a fixed direct voltage so that the direct-current amplifier may amplify a positive signal, eliminating the need for a negative voltage supply. The input voltage is compared with the output voltage fedback through the voltage divider and amplified as a 60-cps signal. A clamping phase-sensitive detector, together with the direct-current amplifier, provides a direct output potential.

Degenerative feedback is necessary to provide correction for thermal electromotive forces which would mask the desired signals in the converter and the amplifier.

Equalization has been provided by means of a shunt capacitance and a series resistance at several places in each channel. This equalization adjusts both the frequency range and the magnification at a particular frequency so that the output of the system is nearly proportional to the displacement of the earth over a wide frequency range. Figure 4 shows the response of one horizontal channel.

Driver Amplifier

The driver amplifier, a balanced direct-current amplifier with additional equalization, includes an input attenuator so that the amplification may be adjusted to compensate for the fact that the seismic background varies from day to day and from season to season.

Timing Impulses

A standard frequency of 100 cps, brought in by telephone line from the General Radio Primary Frequency Standard at the Electrical Engineering Building, is divided by a motor-driven gear chain and cam switch assembly to provide the timing impulses. The two timing pens are mounted between the three pens driven by the amplifier. Timing information is presented to the two pens at 10-second, 1-minute, and 1-hour intervals. When the mechanism for the time coding is completed, the time can be read on the seismogram to an accuracy of one second over a week's interval.

Penmotor Recorder

Since a commercial penmotor recorder having the necessary characteristics as outlined above was not available, the recorder unit shown in Fig. 2 was developed. Starting with a Sanborn "Twin-Viso" Model 60-1300 drive unit, a triple pole-piece assembly was built to replace the original double pole-piece assembly in order to provide three galvanometers for recording the three components of the earth motion. The heated stylus pens on the original galvanometer units were adapted for ink recording by the addition of modified hypodermic needles and a common inkwell. Ink of the fountain pen variety has proved quite satisfactory. The pens have not clogged in three months of continuous operation as long as the inkwell was kept full. A 1,500-ft paper supply with a take-up reel was provided so that the system will operate unattended for up to six days. An economical paper was found in white butcher paper respooled to a 5-in. width. Paper cost is now 35 cents per day, compared with $2 for the photographic paper originally used.

System Tests

In the development of instruments it is important to have available simulated signals for input so that

(Continued on page 32)

APPARATUS FOR COUNTERCURRENT DISTRIBUTION FRACTIONATION OF MULTICOMPONENT SYSTEMS*

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B.S. in Chemical Engineering, June, 1953

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Introduction

The separation of polycomponent mixtures by multistage countercurrent distribution procedures has received wide attention in the past decade and has been developed in many ways as an exceedingly powerful analytical tool. Chromatography, a type of countercurrent distribution process, has already been the key to solution of a host of separation problems, and without doubt its possibilities and achievements will be markedly extended in the future. However, in spite of the general simplicity of column or paper chromatographic methods and the large number of separation stages which sometimes can be obtained, the technique, in all its many branches, is plagued with difficulties which often tax the ingenuity and patience of the investigator, and may, even after long effort, prove insurmountable with regard to the problem with which he is concerned. These difficulties arise primarily from the fact that the properties of "columns" of the discontinuous immobile phase are not under direct control of the investigator. It is seldom possible to predict the number of effective separation stages in a chromatographic process, or the changes which will arise from alteration of column dimensions, solvent composition, flow rate, particle size, and other pertinent variables. Also, the determination of partition coefficients of solutes and phase volume ratios under the precise conditions of the separation process is seldom possible, so that calculation of separability of solutes cannot readily be conducted. Other difficulties arise from the fact that mass transfer rates between phases are usually diffusion-controlled so that very slow flow rates may be required to attain good separation of solutes, precluding the possibilities of chromatography with some unstable substances.

To avoid the empiricisms and other difficulties of chromatography and yet to retain the resolving power of the multistage distribution process, numerous mechanical contrivances have been developed or suggested. For the most part, these are concerned with partition of solutes between two immiscible liquid solvent phases, but, in some cases, they have been extended to solid-liquid and gel-liquid systems. The literature contains many references to use of various types of apparatus for accomplishing continuous steady state separations,[1,2,3] or batch fractionations.[4,5,6,7] Only the apparatus designed to bring about batch fractionations will be here considered. This type of device, in general, can be classified as either continuous or discontinuous in operation.

Continuous devices in some ways are closely analogous to chromatographic columns in which the mobile solvent phase is caused to flow continuously through cells containing discrete quantities of the immobile

*A joint contribution from Pulp Mills Research and the Departments of Chemistry and Chemical Engineering, at the University of Washington.

†Now president of the Food, Chemical & Research Laboratories, Inc., Seattle.

solvent phase, or, conversely, the moving solvent phase may flow discontinuously through restricted regions of the immobile phase. All such devices are characterized in principle by non-equilibrium operation in which a concentration difference exists to provide the potential necessary for solute transfer between phases. One such device, developed in these laboratories, is described in this paper.

Discontinuous countercurrent distribution devices may be likened to a linear assembly of separatory funnels in which increments of one mobile solvent phase are equilibrated with an increment of an immobile phase, separated, and then passed on to the next compartment containing another increment of immobile phase. Performance of these devices does not involve kinetic factors since migration and dispersion of a solute through the successive cells of the apparatus is determined solely by the partition coefficient of the solute. This, of course, may vary with the concentration or the presence of other solutes to yield skewed distributions of solute among the cells of an apparatus, but such effects are often of minor significance and may be predictable. The development of devices of this latter sort has been pioneered and carried to a high degree of practicality and resolving power by Lyman C. Craig and coworkers.[4,6] The 220-stage apparatus recently described,[6] has given separations of many complex mixtures, especially in the biochemical field.[8,9]

In these laboratories such separation techniques have been of special interest in connection with studies on lignin, cellulose, and related products, and a modified Craig machine has been developed and constructed. (See Fig. 1.) This machine will be described and compared in theory and practice with the continuous countercurrent device mentioned above.

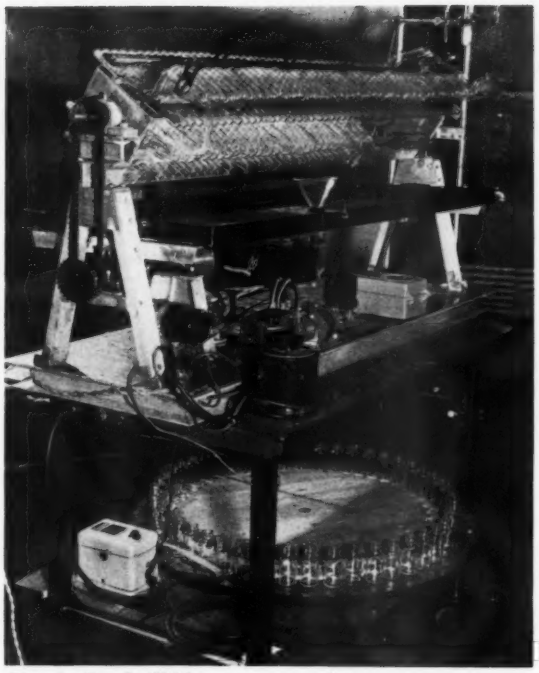

Photo by Ray O. Welch

FIG. 1. GENERAL VIEW OF CRAIG-TYPE COUNTERCURRENT DISTRIBUTION MACHINE

Modified Craig Machine

Our modification of the Craig machine involves no changes in principle or theory of the separation process. Significant changes have been made only in the cell design (Fig. 2) to permit simpler construction and assembly and greater ruggedness, and in the breakdown of the drive mechanisms into separate units, each operated from a multicam timer to reduce complexity and provide greater flexibility in the various steps of the operating cycle. These steps are illustrated in Fig. 3.

The theory of separations for this type of process comprising successive equilibrations and transfers in multiple cells, follows the binomial expansion law, and has been discussed by Williamson and Craig[10] and many others. Similar analyses have been applied to the chromatographic process by Martin and Synge[11] and Mayer and Tompkins,[12] although the assumptions of successive transfer of equilibrated finite increments of mobile phase are not truly applicable in the non-equilibrium situations of the chromatographic columns.

Assuming equilibrium between phases and constancy of partition coefficients, the distribution of a solute in the cells of an apparatus after a given number of transfers, the concentration of a solute in the effluent from the final cell, or the separability of two solutes can all be predicted from knowledge of partition coefficients. Thus, using the terminology of Mayer and Tompkins,[12]

$$L_{n,p}=\left[\frac{n+p-1)!}{(n-1)!\,p!}\right]\left[\frac{C^{n-1}}{(1+C)^{n+p}}\right], \qquad (1)$$

where $L_{n,p}$=the fraction of a solute contained in the mobile phase of the pth cell when the nth increment of mobile phase has equilibrated in that cell. The corresponding fraction of the solute in the immobile phase, $S_{n,p}$, is obtainable from the relation:

$$\frac{S_{n,p}}{L_{n,p}}=C, \qquad (2)$$

where C=the mass partition ratio of a solute, i.e., the ratio of solute concentration in the immobile and mobile phases multiplied by the ratio of the volumes in which these phases are present.

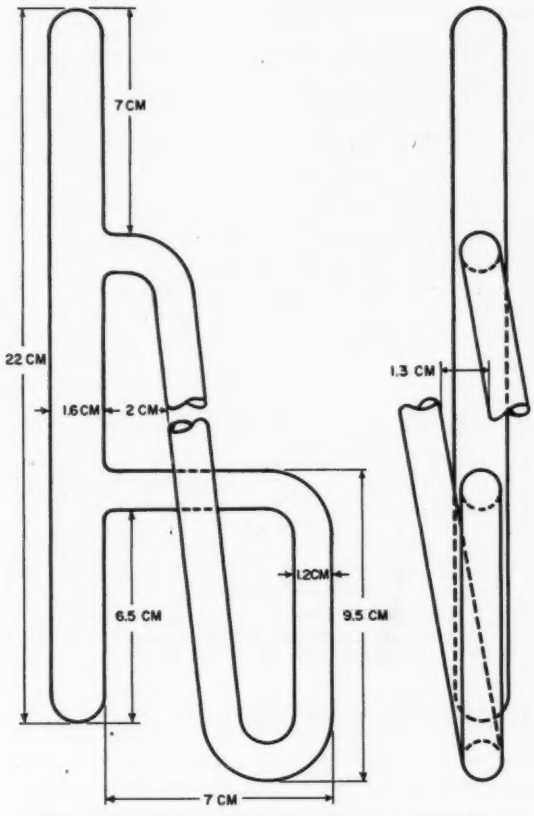

FIG. 2. SKETCH OF PYREX GLASS CELL (½ actual size)

When p is taken equal to the total number of separation cells in the apparatus, $L_{n,p}$ represents the fraction of a total mass of solute which leaves the apparatus in the nth increment of mobile phase. Elimination of factorials from Eq (1) by Stirling's approximation, and differentiation, yields

$$L_{n,p\ (\max)} = \frac{1}{\sqrt{2\pi pC\ (1+C)}}, \qquad (3)$$

and

$$n_{\max} = pC\,. \qquad (4)$$

When the number of plates or cells is large, the distribution of a solute in the effluent approaches a normal probability curve for which the number of transfers representing a standard deviation from the maximum is as follows:

$$\frac{n - n_{\max}}{t} = \sigma = \sqrt{pC\ (1+C)}\,, \qquad (5)$$

where t is the sigma unit, and σ, the standard deviation.

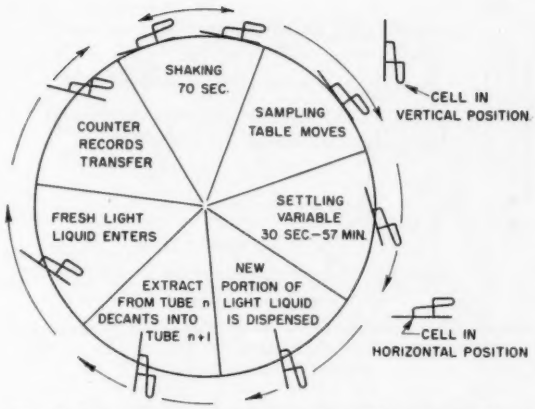

FIG. 3. SCHEMATIC REPRESENTATION OF MOTION OF CELLS DURING ONE TIME CYCLE

The curve showing distribution of solute among the cells of a machine may be readily constructed by these equations from tables of the probability function or may be linearly represented on graph paper with probability integral ruling. Separability of solutes may be easily calculated from predicted elution curves plotted on probability paper.

Thus, predicted separation of propionic from acetic acid is shown in Fig. 4, together with experimental results obtained with the 79-cell apparatus described above, for acetic and propionic acids partitioned between water and n-butanol. Figure 5 shows the same data plotted on probability paper and indicates the convenience of this type of representation.

Continuous-Flow Rotary Apparatus

A continuous-flow rotary multistage fractionation apparatus has also been designed and built in these laboratories. This apparatus is in the form of an elongated cylinder built of alternate discs, or tori, and separatory rings, as sketched in Fig. 6. Each disc has a hole at the center to permit continuous flow of the lighter liquid phase from cell to cell. The heavier liquid phase is retained in the bottom of each cell and the amount of this phase in each cell is controlled by tilting the entire apparatus to any desired angle before admission of the lighter liquid. In operation, the apparatus is supported on power-driven rollers at a small angle with the horizontal, and is rotated at a velocity sufficient to cause mixing of the two phases but insufficient to cause emulsification or carry-over of the heavier phase. The solute mixture to be separated is placed in the first one or several plates, and then the lighter phase is flowed continuously into the first cell and is collected continuously from the last cell by means of an automatic fraction collector (shown beneath the table in Fig. 1).

The theoretical performance of this type of separation device for assumed equilibrium operation has

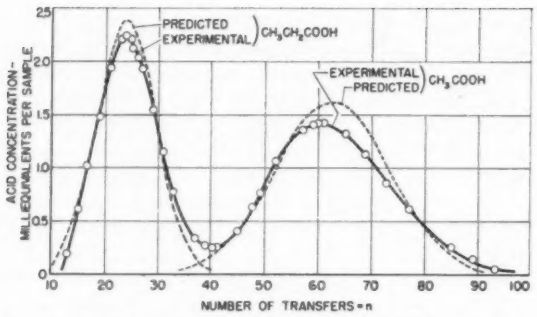

FIG. 4. ACID CONCENTRATIONS VS. TRANSFER NUMBER FOR MULTISTAGE COUNTERCURRENT SEPARATION OF ACETIC FROM PROPIONIC ACID

been developed in these laboratories by Cook and Elgert[13] working with some of the present authors, and also independently by Johnson and Talbot.[1] In the nomenclature of Johnson and Talbot, it has been shown that

$$p_n = \left[\frac{v_a^{n-1}\, b^n\, kt^{n-1}}{(n-1)!}\right]\left[e^{-v_a bt}\right], \qquad (6)$$

where

p_n = concentration of solute in mobile solvent leaving the nth plate of an apparatus operating at equilibrium at time t,
v_a = feed rate of the moving solvent,
$b = k/kV + v\,(1-k)$,
V = total volume per plate of both solvents,
v = volume per plate of stationary phase,
k = distribution coefficient of solute = concentration in mobile phase/concentration in immobile phase.

This expression for the instantaneous concentration of a solute in the mobile phase leaving an n-plate apparatus will also approach a normal probability distribution when n is large. It can be rearranged to a form similar to Eq (1) showing the fraction of the solute in an increment of mobile solvent equal to the volume of mobile solvent contained per plate. Then, in terms of the Mayer and Tompkins nomenclature, one obtains

$$L_{n,p\ (\max)} = \frac{1}{\sqrt{2\pi p}\,(1+C)}, \qquad (7)$$

and

$$\sigma = (1+C)\sqrt{p}\,. \qquad (8)$$

Thus by comparing Eq (7) and (8) with Eq (3) and (5), one sees that when C is large (i.e., when a solute distributes so as to favor greatly the immobile phase, or when the volume of immobile phase is a large fraction of the total plate volume), $1+C$ and

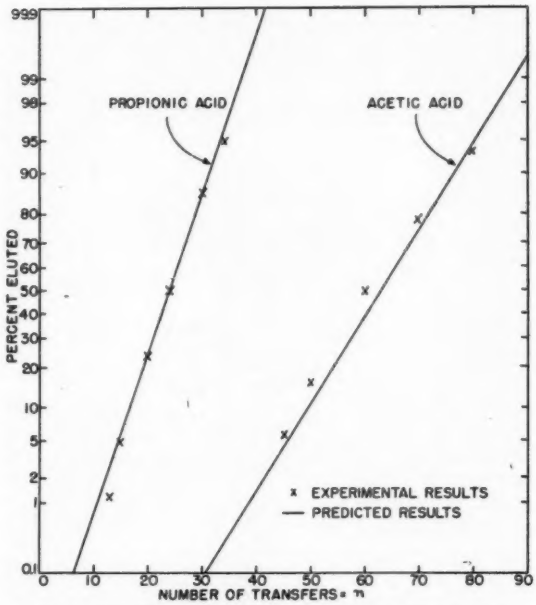

FIG. 5. PER CENT ELUTED VS. TRANSFER NUMBER FOR MULTISTAGE COUNTERCURRENT SEPARATION OF ACETIC FROM PROPIONIC ACID

$\sqrt{C(1+C)}$ are nearly identical, and the dispersion of a solute in a continuous flow apparatus will be only slightly greater than for the discontinuous flow apparatus. Under other conditions, much less dispersion and, hence, increased separation of solutes is found for the discontinuous process.

Studies by Cook and Elgert[13] with some of the present authors, on the performance of a 4-plate rotary apparatus, built of transparent material, have shown that high rates of mass transfer are attainable and that equilibrium operation is closely approachable. A 400-plate apparatus designed and built in these laboratories has been used by E. Reaville[14] for the separation of phenols and other products resulting from the alkaline cleavage of lignin sulfonic acids. The experimental and calculated elution curves obtained for vanillin in the course of one of his experiments shows a plate efficiency of about 70 per cent.

Conclusions

Experience gained with the two types of countercurrent distribution apparatus herein described indicates that both have proper fields of utility. The discontinuous Craig-type apparatus offers the advantages of increased resolving power with fewer separation stages, as well as greater predictability of results and less empiricism, than do chromatographic procedures. The continuous flow apparatus is simpler in operation and is applicable to larger scale separations of a less difficult nature.

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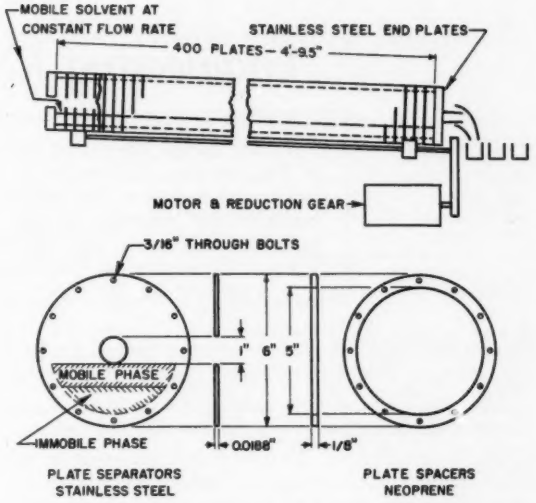

FIG. 6. SKETCH OF MULTIPLATE CONTINUOUS-FLOW ROTARY EXTRACTOR

Large Attendance at Mining and Metallurgical Conference

About 225 members attended the 1953 Pacific Northwest Metals and Minerals Conference which was sponsored by the North Pacific Section of the AIMEE, and held in Seattle, May 14-16, at the Benjamin Franklin Hotel. The program was presented before five divisions: Industrial Minerals, Iron and Steel, Extractive Metallurgy, Physical Metallurgy, and Mineral Industries Education.

The Industrial Minerals Division under the chairmanship of Milnor Roberts, Dean Emeritus of the School of Mineral Engineering, who also presented "A Summary of Industrial Minerals and Rocks and the Fuels of the Pacific Northwest," featured papers dealing with various local and regional mineral resources, including that of Dr. J. I. Mueller, Associate Professor of Mineral Engineering, "Lightweight Aggregates from Pacific Northwest Clays and Shales." Co-authors were former E.E.S. fellows, R. R. Riley and H. L. Shapiro. Dr. Mueller also spoke on "Metallurgical Applications of X-Ray Spectrography" before the Physical Metallurgy Division, and was a luncheon speaker on "Latest Trends in Ceramic Products." Also contributing to this program was Dr. D. Vasarhelyi, Research Engineer of the Civil Engineering Department, with "Plastic Strain and Fracture in Structural Steel Plates with Openings." Other papers presented were as follows:

Industrial Minerals Division: "Natural Gas for the Pacific Northwest" by H. R. Seykota, Portland Gas & Coke Company, Portland; "Reopening of the Wilkeson Property in Pierce County, Wash., to Produce Metallurgical Coking Coal" by Earl R. McMillan, Northwestern Improvement Co., Seattle; "Diatomaceous Earth in Washington" by R. C. Vervaeke, Quincy Corporation, Quincy, Wash.; "The Railroad Dike Pegmatite of Stevens County, Washington" by Harold Kirkemo, U.S. Geological Survey, Spokane; "The Use of Fuels and Electricity in Industrial Minerals Operations in British Columbia" by J. W. McCammon, Department of Mines, Victoria, B.C.; "Analytical Short Cuts by Use of the Spectrograph" by Thomas Matthews, State Department of Geology and Mineral Industries, Portland.

Iron and Steel Division: "Deoxidation vs. Degasification of Alloy Steels Made in Basic Electric Furnaces" by A. L. Ascik, Seidelhuber Steel Rolling Mill Corporation, Seattle; "Sampling Methods at Furnace for Composition Control" by Vincent E. Belusko, Electric Steel Foundry Company, Portland; "Some Short Cuts and Economies in the Heat Treatment of Steel Castings" by Alexander Finlayson,

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Engineering Research Dividends

Recent theses submitted for advanced degrees from the College of Engineering, University of Washington, will regularly appear in abstract form in *The Trend*. Complete copies of these theses are available for reference at the University of Washington Library. Address inquiries to the Director of the Engineering Experiment Station, University of Washington, Seattle 5.

McDONALD, H. A., "Hot Pressing of Low Fusion-Point Clay." M.S. in Ceramic Engineering, 1952.

The feasibility of hot pressing a low fusion-point glacial drift from the Puget Sound area was investigated. A heated mold was used and variables tested were temperature, pressure, time of holding maximum pressure, and packing density of particles. The effects of these variables were measured by determining the bulk density and the porosity of the samples. An almost linear relationship between temperature and density for values above the yield point and a smooth curve for pressure against density make possible predictions of temperature and pressure for any desired bulk density. Porosity asymptotically approached a minimum with increasing temperature in which the minimum was determined by the pressure used. Pressures and temperatures needed to produce a finished material of approximately the same bulk density as material formed and fired by conventional means were very high but not mechanically and physically impossible to attain in a large installation. Increase of the glass content at time of pressing would lower the pressures and temperatures required for any one value of density.

LANE, D. R., "An Experimental Investigation of the Turbulent Boundary Layer on a Flat Plate with Zero Pressure Gradient at Mach Number= 2.97." M.S. in Aeronautical Engineering, 1953.

The paper describes some measurements made in the turbulent boundary layer on a flat plate in the University of Washington Supersonic Wind Tunnel No. 1, at a Mach Number of 2.97, and Reynolds Numbers from 0.47×10^6 to 1.3×10^6. The tunnel is of the intermittent type, and although the test surface was made of plastic to simulate insulated plate conditions as nearly as possible, these conditions may not actually have been realized.

The experimental data obtained were analyzed by a method previously used by Rubesin, Maydew, and Varga, which assumes that insulated plate conditions exist, that the total head is constant through the boundary layer, and that the slope of the logarithmic momentum thickness growth curve has a certain value. Three checks were made to confirm that the boundary layer was fully turbulent. Two of these yielded satisfactory results, while the third was inconclusive.

The values of the mean and local coefficients of skin friction found by this method were in better agreement with those calculated from the Extended Frankl and Voishel Equations than with the values derived from any other theory. The difference with this theory was, at most, 10 per cent for the local coefficients and 3 per cent for the mean coefficient of skin friction.

YIM, W. M., "An Investigation of the Quenching Characteristics of Heavy Media." M.S. in Metallurgical Engineering, 1953.

Numerous quenching media including water, oils and salt baths have been investigated; however, no attempt has previously been made to investigate the possibility of using heavy media for the heat treatment of steels. The rate of heat dissipation in heterogeneous media would differ from that in homogeneous media; therefore, severity of quench of these media would have different values. The purpose of this investigation was to evaluate the quenching constant of two heavy media for the hardening of steel: magnetite suspensions in water and copper-powder suspensions in water, each with two different specific gravities. In determining the severity of quench, two methods were employed: (1) the Lamont method and (2) the cooling-time measurement method. In each method three different types of steel were used: two medium-hardening steels and one shallow-hardening steel. Cooling curve studies revealed prolonged duration of the vapor-blanket stage in the heavy media quench, resulting in slow cooling at this stage. Furthermore, because of excessive viscosity of the media, rates of cooling at the vapor-transport stage were also slow. The severity of the quench value H of the magnetite medium and that of the copper (partly oxidized) medium were approximately

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An Investigation of Pollution in the Yakima River Basin

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The following observations and determinations were made at each survey station, using recommended standard methods: physical appearance, water usage, time and weather, temperature, dissolved oxygen, biochemical oxygen demand, pH, coliform bacteria, color, turbidity, chlorides, alkalinity, hardness, total solids, and sulfates.

Three laboratories were established in the area to facilitate sample collection and testing. Field personnel were divided between laboratories, each of which handled a specific area of the river basin. These laboratories were set up at the Ellensburg, Union Gap, and Sunnyside sewage-treatment plants.

Sample collection was normally performed at midstream and mid-depth and at a location where the stream apparently presented a fairly homogeneous mixture. Samples collected at mid-depth were considered as most representative of water conditions. Bridges rather than shore stations were used wherever possible, since it is rather difficult in many instances to get a representative sample from near the stream bank.

The majority of the samples were collected during the normal daylight working hours. However, three series of samples were collected at night to observe the effect of algae, aquatic growths, and diminished sewage discharge on the water quality. At two stations, samples were collected every two hours for a continuous period of 24 hours to note any significant deviation in water quality with the time of day.

Summary

A total of 83 sampling and observation stations were established in the Yakima River Basin for a study of the effects of municipal and industrial pollution on the bacteriological, chemical and physical properties of the Yakima River, its tributaries, the major irrigation canal waters, and return-water drains. Sources of pollution were determined by field inspections and consultation with municipalities and industry. The period of field sampling extended from June 21 to August 29, 1951. A summary of significant survey observations follows.

1. The Yakima River and its tributaries have a drainage basin of almost 6,000 square miles, and provide water for over a half-million irrigable acres of land which would be virtually unproductive without irrigation. It is one of the largest and most productive of the irrigated areas in the United States, having a 1950 agricultural crop value of over $128,000,000. The water of the Yakima River system, in essence, directly supports the entire basin population of around 200,000 persons.

2. This irrigation water is being polluted by the discharge of raw and improperly treated sewage, by the discharge of poorly treated or improperly treated industrial wastes and by land erosion. Many of these sources of pollution are, in themselves, small but, when taken in the aggregate, produce damaging conditions that will increase with the growth of the basin unless corrected.

3. Hundreds of miles of river, creeks, irrigation canals, and ditches are contaminated by domestic sewage and have bacterial concentrations far in excess of that considered safe and desirable. The bacterial condition of the basin waters is generally poor, but notably so in the rivers and irrigation system below Yakima. This bacterial condition is principally caused by the discharge of raw sewage, inadequately treated sewage, and unchlorinated or improperly chlorinated sewage-treatment plant effluents. Bacterial pollution from Yakima greatly exceeds that from any other source and is primarily responsible for the high bacterial concentrations in the Wapato and Sunnyside irrigation canals.

4. Algae and other aquatic plants, together with turbulent river flow, are responsible for high daytime oxygen concentrations. A marked decrease in oxygen, noted during the hours of darkness, was due to a cessation of, or reverse of plant-life oxygen activities. Night-time oxygen conditions were very poor in the East Toppenish, Wapato Drain No. 2, Moxee and Selah drains and were not satisfactory in the Zillah-Granger section of the Yakima River. Dissolved oxygen values were highest around 4:00 P.M. and lowest around 5:00 A.M. In subsequent studies, therefore, oxygen values should be measured just before sunrise if the minimum conditions are to be determined. The decrease in night-time oxygen concentrations indicates the high pollution load carried by the river system.

5. The usual chemical and physical properties of surface waters (organic and inorganic foreign substances) showed a marked increase in value progressing downstream from Easton to the river mouth at Richland. This change in physical and chemical water quality was caused by return irrigation seepage flows from drains and by industrial and municipal waste discharge. The river and creek tributaries have a general beneficial effect on the Yakima River water quality (Wenas, Satus, and Toppenish Creeks excepted). These values are significant from the standpoint of the use of the water for domestic and industrial water supply.

6. Water velocities in the basin are high over the gravel and boulder stream beds with their shallow flow depths. These flow conditions result in no significant sludge deposits in the Yakima River stream bed, and a short-time period for oxygen reduction reactions in the stream channel. A flow time of only about 2½ days for water not used for irrigation is required from the Yakima River headwaters to its mouth.

The Yakima River and its major tributaries have their flow or run-off controlled by five major reservoirs. A total average of 6,400 cfs of water is used in the various irrigation systems and canals during the irrigation season. A significant portion of the water is used more than once for irrigation owing to the system of drains and return flows to the river. The river flow beyond the Sunnyside diversion dam consists almost entirely of irrigation seepage (return flows) during the height of the irrigation season. Low stream flows are encountered during the late summer and early fall, a time when pollution is at its peak.

7. Practically the entire quantity of sewage and waste discharged to the river above Union Gap, and much of it discharged below Union Gap, is diverted into some irrigation ditch, along with the river water. This results in a potential enteric disease threat to the users of shallow rural water wells and the consumers of farm produce.

Municipal surface water supplies are located above sources of major pollution.

8. Some municipalities, especially Yakima, should operate disinfection facilities at existing treatment plants; many sewage-treatment plants in the basin require better control of chlorination for the removal of basterial contamination from their effluents. Ronald, Roslyn, Cle Elum, and Toppenish need sewage-treatment plants. Other cities need additional facilities at their sewage-treatment plants—notably Grandview and Wapato.

Industries, generally, need to practice better waste prevention and more care in screening and release of wastes to municipal sewers or directly to receiving waters; some industries require waste-treatment plants or other facilities to reduce their waste discharge.

9. The dumping of community refuse of all types into the Yakima River at Easton is producing a localized degrading effect on the river.

Results of Investigation

The investigation served as the basis for a subsequent comprehensive pollution-control program in the Yakima River

Basin, outlined by the Pollution Control Commission.* It provided the impetus for the formation of a voluntary pollution-control committee in the area, made up of mayors of the respective cities, local health department personnel, representatives of local sport groups, and representatives of local industries.

Results so far have been (1) more effective disinfection of sewage discharges throughout the Valley, especially in Yakima, (2) preparation of final plans for sewer-system improvements and sewage treatment in Toppenish, Moxee City, and Terrace Heights (with Mabton discussing the feasibility of sewering their city), (3) reduction by several industries of the amount of waste discharges and greater precaution in their waste treatment, and (4) contribution of the regional information provided by the survey to the report of the U.S. Public Health Service on the Columbia River Basin.

A Comprehensive Pollution Control Program for the Yakima River Basin; Basin No. 25, prepared and adopted by the Washington Pollution Control Commission, March, 1952, Olympia, Washington.

LARGE ATTENDANCE AT MINING AND METALLURGICAL CONFERENCE

(Continued from page 29)

Seattle; "Refractory Practices at Vancouver Steel Company" by G. R. Heffernan, Vancouver Steel Company, Ltd., Vancouver, B.C.; "Use of the Fluidity Test for Temperature Control" by Charles Locke, Atlas Foundry & Machine Co., Tacoma; "Decarburization of Steel in Molten Salts" by F. A. Schaufelberger, and F. R. Morral, Kaiser Aluminum & Chemical Corp., Spokane.

Extractive Metallurgy: "Production of Zirconium" by E. Don Dilling, Bureau of Mines, Albany, Ore.; "New Kaiser Aluminum Plant at New Orleans" by C. P. Love, Kaiser Aluminum & Chemical Corp., Tacoma; "Recent Additions to Tacoma Smelter" by Glenn E. Sigler, American Smelting and Refining Co., Tacoma; "Safety Is Your Job" by O. T. Gallagher, American Smelting and Refining Co., Tacoma; "Utilization of Sulphur Dioxide" by E. G. N. Player, Consolidated Mining & Smelting Co. of Canada, Ltd., Trail, B.C.

Physical Metallurgy: "A Statistical Treatment of Phase Transformations" by Dan McLachlan, Jr., University of Utah, Salt Lake City; "Grain Growth of the Beta Cu-Al Phase" by Margaret A. Ryan and S. A. Duran, State College of Washington, Pullman; " High Temperature, High Pressure Oxidation of Metals II Tantalum in Oxygen," William McKewan and W. M. Fassell, Jr., University of Utah, Salt Lake City; "High Temperature, High Pressure Oxidation of Metals III Zirconium in Oxygen" by Robert C. Peterson and W. Martin Fassell, Jr., University of Utah, Salt Lake City; "Zirconium-Silver System" by R. S. Kemper and O. G. Paasche, Oregon State College, Corvallis; "The Mechanics of Seizing in Metal Wear" by Harry Czyzewski, Metallurgical Engineers, Inc., Portland; "Some Manganese Base Ferro-Magnetic Alloys" by R. Butters and W. M. Armstrong, University of British Columbia, Vancouver, B.C.; "Metallurgical Aspects of Small Gas Turbine Engines" by W. L. Slosson, Boeing Airplane Company, Seattle.

Mineral Industries Education: A panel discussion on "Fundamental Science in Metallurgical Education" with Professor J. Newton of the University of Idaho as chairman, and participants Dr. G. G. Marvin, Division of Raw Materials, U.S. Atomic Energy Commission, Washington, D.C.; Professor W. M. Armstrong, Department of Mining and Metallurgy, University of British Columbia, and F. R. Morral, Research Division, Kaiser Aluminum & Chemical Corp., Spokane.

DATA-RECORDING SYSTEM FOR THE UNIVERSITY SEISMOLOGICAL STATION

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the performance of the instrument may be determined and checked. A small synchro generator unit, with a few milliamperes direct current applied to the rotor and the shaft, rotated at a speed ranging from 0.07 to 20 rps, provides a simulated sinusoidal input signal for routine test and development work. The output voltage is proportional to the frequency. An adjustable speed motor and a gearshift provide the range of frequencies required.

Figure 5 shows the recording of a typical distant earthquake as registered on this system at the University of Washington station.

To provide an adequate and accurate performance check, a standard test has been devised so that weekly tests may be made on the equipment. Each weekly check requires 15 minutes; a complete calibration requires two days. Empirical analysis of the transient response of the system has been made, as well as that of the phase relationship between the motion of the earth and the motion of the pen. The equipment is adaptable for either teleseismic or local seismic investigations. Moreover, because of the electronic adaptability inherent in the system, this seismograph provides an excellent compromise between these two types of seismic investigation with a minimum of instrumentation and a very low cost.

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3. Jacobsen, A., and Holdam, J. V., "Summary of Comparison Circuits" (Table 15.3), *Electronic Instruments*, MIT Radiation Laboratory Series, McGraw-Hill, 1948, Vol. 21, p. 519.

YIM: Quenching Characteristics of Heavy Media

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the same, the values ranging from 0.5 to 0.8 ($in.^{-1}$) depending on the specific gravity of the medium. The data show that increase in specific gravity resulted in decrease in the H value of both the media. For a specific medium, the H values obtained by using different types of steel were not the same, probably because of improper selection of the thermal diffusivity values. The H value seems to vary considerably with temperature, starting with a low value at a high temperature and increasing to a fairly high value at about 800° F. From the limited data at hand, the practical value of the heavy media quench would appear to be questionable.

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58. Preliminary Tests of Thirteen Washington Coals in a Powdered Coal Boiler Plant at the University of Washington. George Samuel Wilson, Harry Fagan Yancey, and Joseph Daniels. 27 pp. 1931.
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67. The Doherty Washer Cooler. Sybren Ruurd Tymstra. 61 pp. 1932.
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85. Discharge of Three Commercial Cippoletti Weirs. Robert Bowman Van Horn. 32 pp. 1935.
87. Open Water Testing of Ship Models. Thomas McKie Rowlands. 20 pp. 1935.
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